Vol. 9 FEBRUARY, 1926 No. 2

Journal

of the

American Ceramic Society

Abstracts Bulletin

A Monthly *Journal* Devoted to the Arts and Sciences
Related to the Silicate Industries

CONTENTS

The Journal:

An Ultramicroscopic Motion Picture Study of the Relation of Colloidal Content and Plasticity in Clays—France 67
The Minerals of Bentonite and Related Clays and Their Physical Properties—Ross and Shannon 77
Influence of Composition of Body and Glaze on the Physical Properties of a True Porcelain—Lee 97
Influence of Fe_2O_3 and TiO_2 on Pure Clays—Kuechler 104
Elimination of Limestone From Clay—Horning 110
Insulation of Ceramic Kilns—Kennedy 114

Ceramic Abstracts 41

The Bulletin:

Editorial 91
Papers and Discussions:
Monograph and Bibliography on Terra Cotta—Wilson 94
Practical Considerations Regarding Enameling Furnaces—Darrah 145
Dynamic Symmetry—Gugle 157
Modern Ceramics of Art—Bergmans 161
Activities of the Society 164
Notes and News 168

Advertisers' Index 17

Plant where fat Minpro Spar is ground by the most modern equipment

MINPRO SPAR

Quality

The
ROESSLER & HASSLACHER CHEMICAL CO.
New York

Chicago	New Orleans	Pittsburgh	Philadelphia
Boston	Cleveland	Baltimore	Kansas City
	Trenton	San Francisco	

L&N AUTOMATIC

Potentiometer Pyrometers

Give your firemen exact operating information. Will also produce accurate records on wide (ten inch) charts.

Save fuel by knowing your temperatures exactly

Catalog 87-K Tells How

Free on Request

LEEDS & NORTHRUP COMPANY
4901 STENTON AVENUE, PHILADELPHIA

LEEDS & NORTHRUP

Chicago, Ill. Los Angeles, Calif. San Francisco, Calif. Cleveland, Ohio

H F & G PRODUCTS ARE RELIABLE

CONTROL of all the processes in the manufacture of Ceramic chemicals by **H F & G** from the raw materials to the finished product insures uniformity of excellence.

The wide range of requirements and varied applications demand such control. Our years of experience, close study of physical and chemical properties, etc. is your insurance of quality.

Look for the well known **H F & G** mark.

THE HARSHAW FULLER AND GOODWIN CO.

Cleveland

Chicago New York Philadelphia

JOURNAL
OF THE
AMERICAN CERAMIC SOCIETY

A monthly Journal devoted to the arts and sciences related to the silicate industries.

Publication Office: 450 Ahnaip St., Menasha, Wis.
Editorial and Executive Offices: Lord Hall, O. S. U., Columbus, Ohio.
Committee on Publications: F. K. PENCE, Chairman; W. E. DORNBACH, F. C. FLINT, M. L. HARTMANN, Ross C. PURDY.
Editor: Ross C. PURDY; Assistant Editor: EMILY C. VAN SCHOICK; Associate Editors: L. E. BARRINGER, E. W. TILLOTSON, ROY HORNING, R. R. DANIELSON, A. F. GREAVES-WALKER, F. H. RHEAD, H. RIES, R. L. CLARE

Application has been made for transfer of second class entry to the post office at Menasha, Wis.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 16, 1918.

(Copyright 1926, American Ceramic Society)
Twelve dollars a year Single numbers, one dollar
(Foreign postage, 50 cents additional)

Vol. 9 February, 1926 No. 2

ORIGINAL PAPERS

AN ULTRAMICROSCOPIC MOTION PICTURE STUDY OF THE RELATION OF COLLOIDAL CONTENT AND PLASTICITY IN CLAYS[1]

BY WESLEY G. FRANCE

ABSTRACT

Many attempts have been made to account for the plasticity of clay on the basis of colloidal content. If these are warranted then one should find characteristic differences in the colloidal fractions of clay suspensions, when examined ultramicroscopically. Furthermore these differences should serve as an indication of the plasticity. Ultramicroscopic motion pictures were taken of the colloidal fractions of the aqueous suspensions of four clays having different plasticities. Marked differences were found in each instance, which indicated the relative order of the decreasing plasticity of the clays examined to be: English china clay; South Carolina kaolin; North Carolina kaolin; and fireclay semi-flint. These results tend to support the idea that a definite relation exists between the colloidal content of a clay and its plasticity. Suggestions with reference to the extension of this work are made.

A. B. Searle[2] states that "Plasticity may be defined as that property of a material which enables it to change its form without rupture, the new shape being retained when the deformatory force is removed." From a practical consideration, a clay must also possess "binding power" in addition to the above property in order to be considered plastic, at least by most clay workers; however, the term has been used rather loosely, in some cases to designate "binding power" and in

---

Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Columbus, Ohio. February, 1925.

[1] Received December 22, 1925.

[2] Third Colloid Report. Brit. Assoc. Advancement of Sci. **124A** (1920).

others in the strict sense of the definition quoted. The work of Bingham[1] has done much towards making a better understanding of plasticity, especially in emphasizing its complex nature, as expressed in the conclusions arrived at concerning its two fundamental properties "yield value" and "mobility." These conceptions will doubtless prove to be of considerable value in the study of the plasticity of clays.

Despite the fact that plasticity has long been regarded as one of the most important properties of clay and has been the subject of many investigations, no adequate explanation has yet been offered for it.

Numerous attempts have been made to account for the plasticity of clays on the basis of the colloidal content. Schloesing[2] in 1874 thought that he detected, in clay, an amorphous material, corresponding in composition to kaolin, having colloidal properties, and to the presence of which he attributed the plasticity. Seger[3] expressed the opinion that the plasticity was, perhaps, due to the molecular arrangement of the fine particles of a special form of hydrated aluminium silicate existing in the clay.

Later Rohland and others were led to somewhat similar conclusions.[4] Among those who have opposed the colloid theory of plasticity are H. Le Chatelier[5] who held the presence of fine crystalline lamellae responsible for it, and in support of this opinion showed that mica and glauconite when ground fine enough became plastic. Similarily A. Atterberg[6] demonstrated that $BaSO_4$, CaF_2, $BaCO_3$, $SrCO_3$ and minerals that split into fine scales or plates, when sufficiently finely ground in the presence of water, also became somewhat plastic. R. C. Purdy[7] stated "plasticity is the result of purely physical conditions and properties, adsorption, solution, molecular attraction and high surface tension."

From a consideration of the foregoing references it is apparent that the term "colloid" has been used, at least by many of the earlier investigators, in the same sense as that originally intended by Thos. Graham,

---

[1] Fluidity and Plasticity. McGraw-Hill Book Company, 1922.

[2] *Comptes rendus*, **79,** 376, 473 (1874).

[3] *Thonindustrie Ztg.*, **2,** 37 (1877).

[4] P. Rohland, *Zeit. Anorg. Chem.*, **31,** 158 (1902); *Z. Electrochem.* **15,** 540–4 (1909); *Sprechsaal*, **42,** [1–3], 655–57 (1909); *ibid.*, **47,** 129–36 (1914); *Kolloid Zeit.*, **13,** 62–3; (1913); Van der Bellen, *Chem. Zeit.*, **27,** 443 (1903); A. S. Cushman, *Trans. Amer. Ceram. Soc.*, **6,** 65 (1904); *ibid.*, **8,** 180 (1906); H. E. Ashley, *Trans. Amer. Ceram. Soc.*, **11,** 530–95 (1909); Bureau of Standards, *Tech. Papers*, **23**; A. V. Bleininger, *Jour. Ind. Eng. Chem.*, **12,** 436–38 (1920); G. A. Bole, *Jour. Amer. Ceram. Soc.*, **5,** 469 (1922); J. W. Mellor, *Trans. Ceram. Soc.* (Eng.), **21,** 91–103 (1921-22).

[5] Van Bemmelen, Godenboek, pp. 163–72.

[6] *Z. Angew. Chem.*, **24,** 928–9 (1911) and R. Rieke, *Ceramique*, **15,** 87 (1912).

[7] *Jour. Amer. Ceram. Soc.*, **5,** 475 (1922).

namely, to indicate a kind, rather than a state of matter. When used in the latter and more modern sense many of the objections are met. Thus the statement of R. C. Purdy, quoted above, is not out of harmony with the fundamental conceptions of the colloidal state of matter, when we refer to the colloidal content of a clay as being that fraction made up of particles within colloidal dimensions, approximately between the limits 0.1μ–$1\mu\mu$, since the suspension of such particles in most fluids gives rise to stable systems possessing large surface area and consequently great surface energy accompanied by marked adsorption effects.

Since the present paper has for its object the ultramicroscopic investigation of the colloidal content of several clays with the view of determining what, if any, relation may exist between plasticity and colloidal content, further discussion of the various theories of plasticity will be deferred until a later paper.

As already shown it is not difficult to find many references in the literature which state that the colloidal content of a clay determines its plasticity. If such statements are warranted, then one might reasonably expect to find characteristic differences in the colloidal fractions of suspensions of clays having different plasticities, when examined with the ultramicroscope, since the particles constituting these fractions are too small to be observed by other means. P. Ehrenberg and G. Given[1] and also J. Alexander[2] have made use of the ultramicroscope in the study of clays. In neither case, however, was any direct correlation made between the observed results and the plasticities of the clays.

In the present work ultramicroscopic motion pictures were made in order to facilitate the comparison of the colloidal content of the clays investigated.

The value of the motion picture camera in colloidal investigations was early demonstrated by Victor Henri[3] in his motion picture study of the Brownian Movement of rubber latex particles by means of a high power microscope. Two or three years later Jean Comandon[4] combined the motion picture camera with the ultramicroscope and ultramicroscopically photographed minute organisms and particles of colloidal dimensions.

Little use, however, was made of the motion picture camera in this connection until employed by Darke, McBain and Salmon[5] in a study

[1] *Kolloid, Zeit.*, **17,** 33–7 (1915).

[2] *Jour. Amer. Ceram. Soc.*, **3,** 612 (1920).

[3] *Societe Francaise de Physique Bulletin des Seances*, **4,** 45, 61 (1908).

[4] F. A. Talbot, "Practical Cinematography and Its Applications," p. 169, J. B. Lippincott, 1913.

[5] *Proc. Roy. Soc.*, (London) **98A,** 395 (1921).

of soap structures, and by W. G. and H. C. Eddy[1] in a study of emulsions. The first investigation in which the motion picture camera and ultramicroscope were combined in this laboratory was in a study of the Brownian Movements of basic lead carbonate suspensions and of red gold sols both in the presence and absence of gelatin. An account of this work was prepared for the April, 1924, meeting of the American Chemical Society, and an abstract published in the Abstracts of the Inorganic and Physical Chemistry Division.[2] Due however, to the inability of the writer to attend the meeting the paper was presented by title only. Subsequently E. O. Kraemer presented a paper entitled "Studies with the Kinoultramicroscope," at the Second Colloid Symposium[3] in June, 1924, and more recently E. P. Wightman and A. P. H. Trivelli[4] have published a motion picture study of rubber latex particles.

Apparatus

In our earlier work a Pathe Field Camera employing standard 35 mm. motion picture film was used. Because of the inconvenience encountered in the finishing of this film with the limited dark room facilities at hand, attempts were made to use one of the smaller cameras employing 16 mm. film. The camera finally selected was a Bell and Howell Filmo camera provided with an F 3.5 lens and using 16 mm. Cine Kodak Film. The remainder of the apparatus consisted of a Siedentopf Cardioid Ultramicroscope, a cooling cell, a direct current arc lamp, and an adjustable support for the camera. The arrangement of this apparatus is shown in Fig. 1, in which A is the arc lamp, c the cooling cell, M the quartz chamber containing a few drops of the colloidal system, K the camera and s the adjustable support.

As the camera was not designed for microscopic work the following method of focusing was adopted. When the field to be photographed was found, a brass cylinder L, (2 cm.$\times$6 cm.), supporting a ground glass was placed on the ocular in the position indicated in Fig. 1. The image of the field was then focused on the ground glass, after which both the cylinder and ground glass were removed. A shorter brass cylinder L' was then screwed into the lens mounting of the camera K in place of its regular lens, the optical system of the ultramicroscope serving in its stead. The length of the cylinder L' was such that when fitted snugly against the shoulder of the lens mounting the distance

[1] *Jour. Ind. Eng. Chem.*, **13**, 1016 (1921).

[2] Abstracts of papers to be presented before the Division of Inorganic and Physical Chemistry at the Washington Meeting, No. 30.

[3] Colloid Symposium Monograph, **2**, 57 (1925).

[4] *Jour. Ind. Eng. Chem.*, **17**, 164 (1925).

from the outside end of the cylinder to the film in the camera was exactly 6 cm., that is, the length of the cylinder *L*. Without changing the focus obtained with cylinder *L*, the camera was brought into the position shown in Fig. 2, such that the end of *L'* just came in contact with the top of the ocular, fine adjustment being made by means of the slow motion screw *B*. In this position then the film within the camera occupied the same relative position as the ground glass *G* of Fig. 1 on which the image had been previously focused. The pictures were then taken by simply pressing the button *D*, releasing the automatic spring driven motor of the camera. The films were developed with alkaline pyrogallic acid and fixed in a chrome alum bath, washed in running water and air dried. In addition to the cardioid condenser and quartz chamber, the optical system of the ultramicroscope consisted of a glycerine immersion objective (num. apert. 0.85) and an orthoscopic ocular (F 15 mm.). In some instances photographs were made using the regular camera lens; this simply necessitated the use of a shorter brass tube which was screwed onto the lens collar, and the same procedure followed as already given.

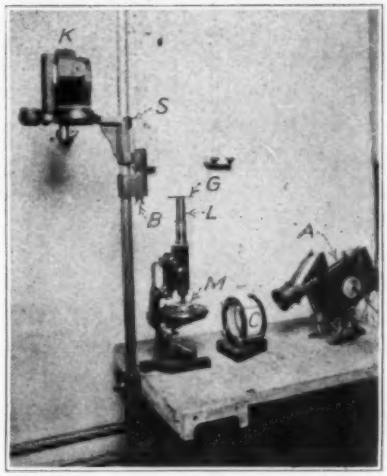


FIG. 1.—Arrangement for focusing

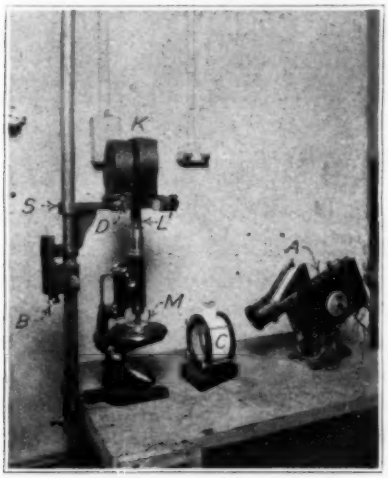


FIG. 2.—Camera in position for taking pictures.

Clays Studied

The clays selected for investigation were an English china clay, a North Carolina kaolin, a South Carolina kaolin and a fireclay semi-flint. Aqueous suspensions of these clays, having a concentration of about 0.1 gram per cc. were furnished by G. A. Bole and H. C. Harrison of the Columbus Station of the Bureau of Mines. The colloidal fractions were obtained in the following way. 0.5 cc. of the thoroughly

shaken suspension was placed in a 20 cc. test tube; 15 cc. of distilled water were then added, and after vigorous shaking the test tube was set aside and the contents permitted to settle undisturbed for four hours. At the end of this time the top cc. was removed and diluted ten times. A few drops of this suspension were then placed in the quartz chamber, and the chamber mount *M* placed in the position shown in Figs. 1 and 2. A field was selected and the procedure as already outlined was followed. Three different aqueous suspensions of English china clay were studied: one untreated, one made slightly alkaline with NaOH, and one slightly acid with acetic acid.

Figures 3, 4 5, 6, 7 and 8 are photographic prints of the negatives obtained. The number of light areas can be taken roughly as an indication of the quantity of colloidal material present, and the size of the individual areas can likewise be taken as an indication of the tendency for flocculation.

Figure 3 is the print of the untreated English china clay. This shows a considerable number of large light areas indicating a high colloidal content, and high plasticity based, of course, on the assumption that the colloidal content bears a direct relation to the plasticity of a clay.

Figure 4 is that of the English china clay made slightly alkaline. The decrease in size of the light areas indicates the deflocculating action of the NaOH.

Figure 5 is that of the English china clay made slightly acid with acetic acid. The appearance of only small areas in the field, is doubtless due to the flocculating action of the acid, which produced aggregates of particles exceeding ultramicroscopic dimensions, which settled out and were therefore not included in the colloidal fraction.

Figure 6 is the South Carolina kaolin. Judged by the same standards as Fig. 3, one would conclude that it had almost as high a colloidal content and perhaps about the same or possibly a little less plasticity than the English china clay. From similar considerations, Fig. 7, which represents the North Carolina kaolin, is unquestionably lower in colloidal content and would likewise be less plastic than either of the other clays. Fig. 8, the fireclay semi-flint, would be the least plastic having a much smaller colloidal content than the others. The four clays would therefore be arranged in the order of decreasing plasticity as follows: English china clay; South Carolina kaolin; North Carolina kaolin; and fireclay semi-flint. With the possible interchange of the first two clays, the above is no doubt the correct order of decreasing plasticity. Since, however, the plasticities of these clays were not measured, it is of course impossible to state just what the correct order should be.

It is evident from this work that an ultramicroscopic examination of the colloidal fractions of the clays, reveals characteristic differences

FIG. 3.—English china clay (untreated).

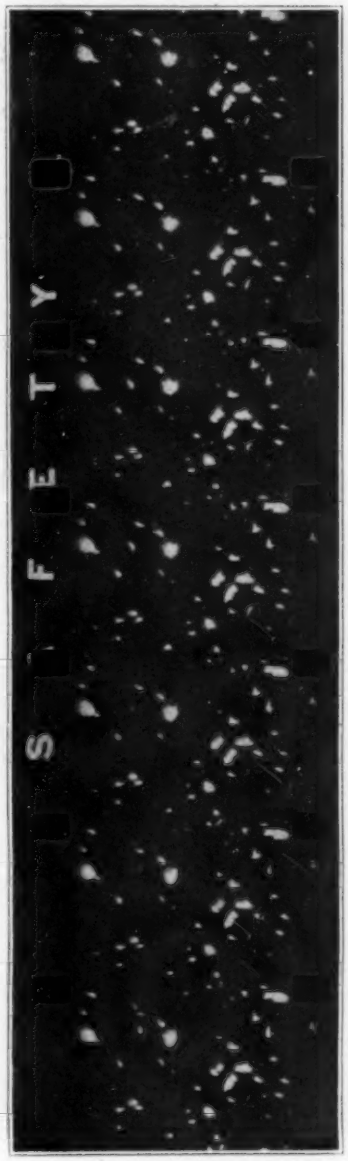


FIG. 4.—English china clay (alkaline).

which apparently afford a means of determining their relative order of plasticity. This would seem to indicate that there is some foundation for the numerous statements found in the literature claiming a relation between plasticity and colloidal content. However, before drawing any

FIG. 5.—English china clay (acid).

FIG. 6.—South Carolina kaolin.

definite conclusions in this connection, the present work should be extended so as to include a wide variety of clays of definitely known plasticity. Furthermore, in order to prevent the possibility of including particles exceeding ultramicroscopic dimensions, the colloidal fractions should be collected by means of a high speed centrifuge. Valuable

FIG. 7.—North Carolina kaolin.

FIG. 8.—Fireclay semi-flint.

information, as indicated by Figs. 4 and 5, could also be obtained from a systematic study of the flocculation and deflocculation effects of electrolytes by means of the ultramicroscopic motion picture method. These and similar problems are now in progress in this laboratory.

Conclusions

1. Attention has been called to the confusion in the use of the term "colloid."

2. A simple and convenient ultramicroscopic motion picture method, employing comparatively inexpensive and readily procurable equipment, for the study of colloidal systems has been described.

3. Characteristic differences have been shown to exist in the colloidal fractions of clays of different plasticities.

4. The relative order of plasticity of four clays has been determined by these differences.

5. Some evidence has been obtained in support of the belief that a relation exists between the plasticity and the colloidal content of a clay.

The writer expresses his thanks to Julius F. Stone through whose generosity the ultramicroscope and motion picture equipment used in this work were provided.

Department of Chemistry,
The Ohio State University.

THE MINERALS OF BENTONITE AND RELATED CLAYS AND THEIR PHYSICAL PROPERTIES[1]

By Clarence S. Ross and Earl V. Shannon

ABSTRACT

Bentonite is a very widely distributed clay material that is the result of the devitrification and chemical alteration of glassy volcanic ash or tuff. Bentonite should be used as the name of a rock derived from volcanic glass and it is commonly composed of the mineral montmorillonite but less often of beidellite. Its characteristic minerals are completely crystalline and have a micaceous habit, high birefringence and facile cleavage. It contains no gel colloids, and few of its crystal particles are so small as to reach "colloidal size." It shows high adsorptive powers and this property is more dependent upon physical form than upon chemical composition. That is upon the micaceous structure and easy cleavage which give very great surface area and the felt-like texture which facilitates permeability.

The clay minerals of the type here described resemble the micas in many ways, but do not seem to possess the marked chemical variability of that group. A large number of analyses of the clay minerals from bentonite indicates that the most widespread of these is montmorillonite with the formula $(Mg, Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot nH_2O$.

A reanalysis of the type montmorillonite from Montmorillon, France, gives the same formula, and the mineral has also been recognized in lithium-bearing pegmatites and in fullers' earth.

A few bentonites are composed of beidellite, a mineral first identified from the gouge clay of ore veins. It has the formula $Al_2O_3 \cdot 3SiO_2 \cdot nH_2O$ where n = about 4, and Al_2O_3 may be partly replaced by Fe_2O_3.

A third micaceous clay mineral has the composition of halloysite $Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$, but it is completely and visibly crystalline and has a high birefringence.

Introduction

Clays are fundamentally minerals or aggregates of several minerals and yet, notwithstanding their universal occurrence and great industrial importance, less is known of them than of any of the widely occurring minerals. Their investigation has been delayed by the fact that they are often composed of complex aggregates of minerals of very fine-grained or amorphous texture, but there is no reason for believing that careful and systematic study by modern research methods will not bring them within the realm of organized knowledge. This situation has led the writers to undertake a thorough study of one group of clay minerals with three main objects in view. The first and most important has been to determine whether the clay minerals can be studied and explained by the methods now at the disposal of the mineralogist. The second has been to extend the knowledge of an important mineral group, and the third has been to point the way and perhaps inspire other workers to extend the investigation to include all the clay minerals.

[1] Printed by permission of the Director of the United States Geological Survey and the Secretary of the National Museum. Recd. Dec. 3, 1925.

For these reasons the minerals of bentonites and related clays have been under investigation in the laboratories of the U. S. Geological Survey and the National Museum for the past two years. The work has had many ramifications; alluring avenues of research have led even into complex problems about the constitution of matter; and results have been attained that throw light on many mineralogical problems.

The clays that have been included in this study are those characteristic of bentonites, the gouge clays of ore veins and the related minerals from altered pegmatites. These are not clays that are extensively used in the ceramic industries but they are pure minerals or are capable of being purified and so constitute a point of departure in a study of clay minerals. They occur with less purity in shales, soils, and even in metamorphic rocks and appear to be more widely distributed than kaolinite which has often been considered the characteristic clay mineral.

The characteristic mineral from twenty bentonites and related clays has been analyzed, and often very careful purification and optical study has been necessary to assure the purity of the material. Over 300 thin sections have been made and examined, and to do this it has been necessary to develop an entirely new technique for grinding thin sections. The new methods make it possible to grind thin sections without the customary use of water and to retain perfectly the original texture no matter how delicate or friable the clay may be. The optical properties have been determined on hundreds of specimens, where the individual mineral grains are usually exceedingly fine grained. This exhaustive work still leaves many problems unsolved, but it is believed that distinct progress has been made and some firm ground has been reached.

The present paper is a condensed statement of the results and deductions that will be of most interest to ceramists, but it is planned to publish the complete results later, either through the U. S. Geological Survey or the National Museum. The study of clays composed of pure minerals with definite properties provides a new approach to the problem of the causes of plasticity in clays, and a paper on the subject is under preparation and will follow this one.

Bentonite

Bentonite has peculiar and perhaps valuable properties that have aroused much interest and speculation, but there has been little agreement as to the physical or chemical nature of the material and no careful investigation of its properties. The present work has shown that bentonite is composed of a definite mineral which can be studied by the

same methods that have been applied to other minerals, and its peculiar properties can be explained on the basis of the ascertained properties of its individual crystal grains. Thus bentonite is completely amenable to the research methods of mineralogy and geology.

The following definition of bentonite is proposed:

Bentonite is a *rock* composed essentially of a crystalline clay-like mineral formed by devitrification and the accompanying chemical alteration of a glassy igneous material, usually a tuff or volcanic ash; and it often contains variable proportions of accessory crystal grains that were originally phenocrysts in the volcanic glass. These are feldspar (commonly orthoclase and oligoclase), biotite, quartz, pyroxenes, zircon and various other minerals typical of volcanic rocks. The characteristic clay-like mineral has a micaceous habit and facile cleavage, high birefringence and a texture inherited from volcanic tuff or ash, and it is usually the mineral montmorillonite, but less often beidellite.[1]

It is advisable to restrict the rock name bentonite to a material derived from volcanic ash, since the inherited structure seems to have almost as great an influence on the physical properties as the mineral composition. It is quite evident that a mineral with the same chemical composition as that found in bentonite can develop in other ways. Thus the mineral that is often found in lithium-bearing pegmatites is undoubtedly montmorillonite and at least some fullers' earth has the same composition, but their origin and texture are different and so they would not be called bentonite. Beidellite, which occurs in some bentonite, is also found in gouge clays that are very different from bentonite.

Bentonites often contain detrital material from various sources in addition to the igneous rock phenocrysts, and sands may be mixed with bentonitic material in all proportions. It is probably best to confine the name bentonite to material with at least 75% of the bentonitic clay minerals and less than 25% of sandlike or other impurities. If it contains between 25 and 75% of sandy impurities it may be called an arkosic bentonite and with less than 25% of the bentonitic clay minerals it may be called a bentonitic arkose. Shales may also contain admixed bentonitic material, but in these its certain identification is very difficult or even quite impossible.

Occurrence of Bentonite

Bentonite has been reported from every state west of the Missouri River and from Kansas, Oklahoma, Texas, Louisiana, Arkansas,

[1] Esper S. Larsen, and Edgar T. Wherry, *Jour. Wash. Acad. Sci.* **15**, 465 (1925).

Tennessee, Alabama, Virginia, Kentucky, Pennsylvania, Minnesota, Wisconsin, and probably other eastern states. It is found in Old Mexico, in much of western Canada, Alaska to beyond the Arctic Circle, in China, and possibly in France. It has been found in the Paleozoic and Mesozoic beds, but is probably most abundant in the Tertiary.

The distribution, uses, physical properties, and bibliography of bentonite are admirably given by Hugh S. Spence[1] in a recent *Bulletin* of the Canada Department of Mines. A large number of analyses are quoted, but these represent the crude samples and are not intended as a study of the composition of the characteristic clay mineral of bentonite.

Volcanic debris has contributed material to the sedimentary beds over wide areas in the western states and these frequently contain much bentonitic material. Renick[2] has shown that this more or less sparsely disseminated bentonitic material may have an important bearing on the chemical composition of ground waters.

Habit and Structure

Bentonite is an extremely variable material in its outward appearance and superficial physical properties. The most widespread color is probably pale buff, cream or dull green, but gray, dull blue, green and pink are not uncommon. Less frequent colors are deep olive green, red, and yellow. Some specimens are nearly white when dry, but pure white is not often seen in bentonites. However, one known deposit yields material that is pure white even after wetting.

Some bentonites are very compact in texture and have a sharp conchoidal fracture. Others are more open and porous, and some have a very loose feltlike texture. After the bentonite was formed, its texture has often been modified by the deposition of material that was carried in solution. Small bead-like grains of calcium or iron carbonate are often seen, and in some deposits calcium carbonate has completely filled the pores and produced a dense hard rock. Small black spots of manganese oxide are found in some deposits and gypsum and barite crystals are abundant in others. Alkalis and alkali salts occur in varying amounts and this rôle will be more fully discussed in page 89.

The study of thin sections of bentonite reveals two outstanding features: (1) that bentonite is derived from volcanic ash, as has been pointed out by Hewett[3] and Wherry,[4] and (2) that its characteristic

[1] Hugh S. Spence, Can. Dept. Mines. Mines Branch.

[2] B. Coleman Renick, "Base Exchange in Ground Water by Silicates as Illustrated in Montana," U. S. Geol. Survey, *Water Supply Paper* **520-D,** 53–72 (1924).

[3] D. F. Hewett, "The Origin of Bentonite," *Jour. Wash. Acad. Sci.*, **7,** 196–98 (1917).

[4] E. T. Wherry, "Clay Derived from Volcanic Dust in the Pierre of South Dakota," *Jour. Wash. Acad. Sci.*, **7,** 576–83 (1917).

mineral is definitely crystalline. The ash structure is perfectly preserved in a large proportion of the sections. Devitrified glass bubbles are sometimes seen; the segments of hollow spheres, the angular or Y-shaped or lune-shaped fragments that result from the fracture of rounded bubbles or groups of bubbles are a widespread type; the flattened plates that are derived from elongated and lens-shaped bubbles are probably most abundant; and pumice fragments with a fibrous habit are not rare.

Thus all the types of structure that occur in glassy volcanic ash[1] are represented in bentonite.

The microscopic examination between crossed nicols of the petrographic microscope shows that the characteristic mineral of bentonite is crystalline, as has long been maintained by Larsen,[2] Wherry,[3] and others. In some specimens the material is very fine-grained but in most of them the crystal grains can be seen even with low magnifications. The mineral has a micaceous habit, and moderately high birefringence perpendicular to the cleavage. The groups of plates that have been derived from a single glass fragment commonly have a definite arrangement, and sharply outline the original fragment. In most types of bentonite the crystal plates stand perpendicular to the original surface of the glass fragment, and the resulting crystalline area is now composed of two parallel rows of micaceous plates that often have a parting line between them. In other specimens the micaceous plates have developed parallel to the sides of the glass. Crystalline areas of these two types appear to show a positive and negative character of elongation but the anomaly is usually explained on an examination with an oil immersion lens which shows the real orientation of the plates. In a few bentonites both orientations are to be seen, and a laminated structure has been observed with two outer rows of plates lying perpendicular to the surface, and separated by a film in which the plates lie parallel to the length of the fragment.

Figures 1 and 2 show photomicrographs of several types of bentonite. All were taken under crossed nicols and the light-colored areas are definite evidence of the crystalline nature of the grains, for no light is transmitted through the upper nicol by noncrystalline material. The high birefringence shows only when the micaceous plates stand perpendicular to the thin section and plates that lie nearly parallel are black or dark gray. The magnification is low in all the sections and so the comparatively large size of many of the individual crystal areas is

[1] L. V. Pirrson, *Amer. Jour. Sci.*, **40** [4], 193 (1915).

[2] E. S. Larsen, Personal communication to Hugh S. Spence in *Bull.* **626,** of the Mines Branch, Dept. of Mines, Canada, 1924.

[3] Edgar T. Wherry, *Jour. Mineralogical Soc. of Am.*, **10,** 65 (1925).

evident. Thus the large platelike fragment of uniform crystal structure in *a*, Fig. 1, is nearly 3 millimeters in length and the larger plates in *a*, Fig. 2, are equally large.

An unusually perfect devitrified glass bubble is shown just to the right of the middle in *a*, Fig. 1.

FIG. 1*a*

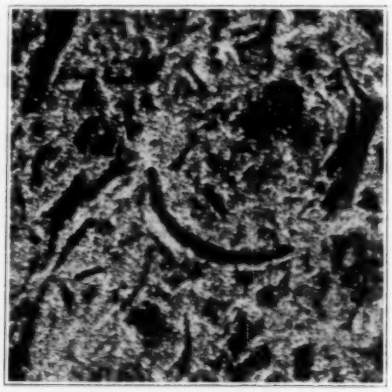


FIG. 1*b*

FIG. 1.—(*a*) Bentonite. Encinitas, San Diego Co., Calif. Rounded, unbroken bubble wall and platy tuff fragments. Crossed nicols. Magnification 20 ×.

(*b*) Bentonite. Dome, Arizona. Gray areas bentonite ground-mass, black residual bubble walls of unaltered glass. Crossed nicols. Magnification 10 ×.

Bentonites with incompletely devitrified glass are not common but a very good example is shown in *b*, Fig. 1. The black areas are isotropic glass and the lighter areas are made up of rather finely granular crystalline material. *a*, Fig. 2, is made up almost exclusively of platy fragments that have altered to very sharply bounded crystalline areas.

b, Fig. 2, is part of a fragment that was originally 6 to 8 decimeters in diameter which came from a coarse tuff. It shows very perfectly the flow structure that is characteristic of many glassy volcanic rocks. All these textures have been retained in a material that is now clay, and yet the volcanic rock structures are as perfect as they could have been on the day that the original glass cooled. The perfection with which structures have been retained is one of the remarkable features of bentonite.

The bentonites that have been derived from a platy volcanic ash commonly show an orientation of the plates parallel to the bedding. There appears to be a loss of volume on alteration from glass to the clay-like material, and the deposit certainly becomes more compact.

During the process the individual fragments become slightly plastic and assume a somewhat crenulated form as they accommodate themselves to the shape of their neighbors. The loss of volume and degree of compacting can not be excessive, however, for the rounded forms of glass bubbles are often practically unmodified by flattening.

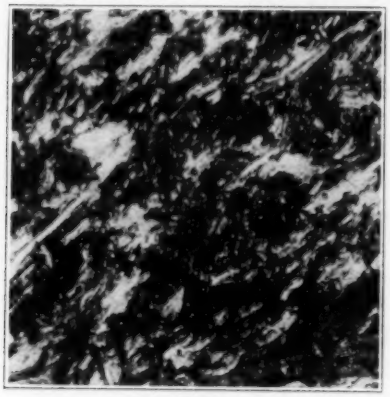


FIG. 2*a*

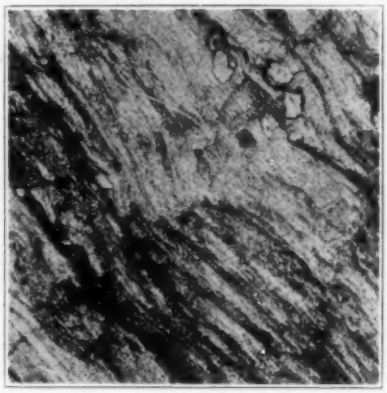


FIG. 2*b*

FIG. 2.—(*a*) Bentonite. Brown property, Nevada. Platy volcanic ash fragments. Crossed nicols. Magnification 10 ×.

(*b*) Rideout, Utah, fragment of volcanic flow rock altered to bentonite. Small rounded areas are feldspar. Crossed nicols. Magnification 20 ×.

The conspicuous and often coarsely crystalline texture of bentonite precludes a purely "colloidal" explanation of its physical properties. Bentonite has long been a favorite theme for those who believe that adsorptive properties are inseparably associated with colloids, and it has been one more substance for which the colloidal theory has been invoked. Thus the literature is full of references to it as a "colloid" or as a "typical colloid." Any material can be dispersed till its particles reach dimensions that have been termed colloidal, and variable proportions of bentonite no doubt reach this arbitrary degree of dispersion. A large proportion of the crystalline grains can be observed with moderate magnifications in a slurry made from most bentonites, and the proportion of large discrete mineral grains is far greater in the undisturbed dry bentonite. However, if those assuming the "colloidal" nature of bentonite clearly recognized that it was a finely divided crystalline material as are most colloids,[1] the difference of view would not be great for then there would be only a question of the degree of

[1] Svedberg, *Chem. Rev.*, 1 [3], 629 (1924).

dispersion. However, there appears to be a fatal tendency to forget all about crystalline dispersoids and to think of so-called colloids in terms of amorphous gels which have been defined as a coagulated liquid-liquid system. Thus many have reasoned on the basis of its adsorptive properties that bentonite was a colloid and then assumed that it was an amorphous gel, all unmindful that direct observation is the first step in research. Bentonite does show very great adsorptive powers but this is the result of the physical structure that gives great surface area and is due only in a minor degree to the small size of the individual crystal grains.

The minerals that are associated with the clay-like devitrification products of glass and that represent igneous rock phenocrysts are orthoclase, plagioclase, biotite and augite and less often hornblende, muscovite, zircon, apatite, etc.

Quartz that was clearly an essential mineral in the original rock is present in some bentonites, although usually in rather limited amount, but it is entirely absent in others. Bentonite also contains quartz of detrital origin, that evidently became mixed with ash that fell upon land and was later reworked before deposition in the sea.

The alteration of the glassy igneous material into bentonite is so complete that it is usually possible to arrive at the original composition only by inference. Feldspar (usually orthoclase) is the predominant phenocryst and is often the only one present, and biotite is not rare. Thus the phenocrysts are generally those that are characteristic of quartz-free trachytes, latites, quartz latites, and possibly quartz-poor rhyolites but seldom quartz-rich rhyolites. Trachyte and latite are composed of silicate minerals with the highest possible silica ratio and rhyolite is composed of the same type of silicates plus quartz, and it is to be noted that these rocks so far as known give rise to bentonites that are composed of montmorillonite, the clay mineral with an alumina-silica ratio of 1 to 5.

The arkosic bentonite of southwestern Arkansas is composed of the clay mineral represented by analysis 21, page 94, and is the result of the alteration of nephelite-bearing rocks. The iron-rich bentonitic clay represented by analysis 25, page 94, is the result of alteration of an olivine basalt. Both these bentonites are characterized by the beidellite type of clay mineral with an alumina-silica ratio of 1 to 3, and both are derived from rocks with a deficiency of silica. The evidence at hand does not permit broad generalizations, but it seems quite probable that glasses very high in silica are fairly stable and do not readily alter to bentonite. The silica content above which a glass is not likely to alter to bentonite is perhaps about 68 or 70% SiO_2, although the limit is probably far from definite. Glasses with an intermediate

silica content that approach a feldspar glass in composition alter to montmorillonite with a 1 to 5 ratio of alumina to silica and those low in silica alter to beidellite with a 1 to 3 ratio.

The conditions that favor the change from glass to bentonite are not well known. Many bentonites occur in marine sediments, but others are in non-marine beds, although the possibility that the ash fell in saline lakes cannot always be excluded. The process of alteration is largely one of hydration accompanied by devitrification and leaching out of alkalis and possibly of other bases. It may be that bentonite is merely the result of the instability of glass of a certain composition in the presence of water and the salts that are normally dissolved in it, and that no unusual conditions are required for its formation. The wide distribution of bentonite also suggests that its formation is not dependent upon special conditions.

Other workers on the subject have come to the conclusion that the active gases that are abundant in volcanoes of the explosive type have played a part in the production of bentonite by initiating the alteration that was completed after the deposition of the ash.

The great purity of many bentonites, and the preservation of delicate structures like bubble walls and glass shreds, show that the ash from which it was derived must have been deposited directly from the air. The wide extent of those deposits and their distance from a known volcanic source emphasize the stupendous proportions of some of the volcanic eruptions of the past.

Some bentonites contain much non-volcanic detrital material and have lost the characteristic ash structure. This type probably first fell upon land and was later reworked and redeposited like other detrital sediments. Sometimes only the upper part of the bed is reworked and this is probably the result of wave action in shallow water.

Different bentonites have quite different physical properties. Most of them swell slightly and crumble in water, but do not become plastic. Most of them contain little material that remains in suspension more than a few hours, even after having been agitated in water for many hours. A few become plastic, swell greatly, and a large proportion of the material may remain in permanent suspension. This difference is partly due to variations in structure, and possibly in part to natural salts that act as flocculating and deflocculating agents. The swelling is primarily due to the micaceous habit and the very slight cohesion between crystal plates, so that films of water penetrate between them. Thus on wetting and slaking, the crystalline aggregate that makes up the bentonite, subdivides into micaceous plates that have large lateral extent but many of them probably have a thickness that is best expressed in molecular dimensions.

Wherry[1] has suggested the term "one dimensional" colloid for the very thin micaceous plates of dispersed bentonite which he says "exhibit optical and physical properties which indicate that their grains are of visible dimensions in two-space directions, but submicroscopic and colloidal in the third, perpendicular to the micalike plates." This peculiar micaceous habit and the easy cleavage, which is only potential in the original bentonite, but that may become actual in a slurry, results in a material that has tremendous surface area ready to exert adsorptive powers, and gives the greatest possible ratio between area and mass. The open felted texture allows water to quickly penetrate throughout the mass so that the entire surface area of the micaceous plates is quickly covered by a film of water. This happy combination of large surface area and permeable texture gives bentonite the greatest efficiency for adsorption that nature ever seems to have devised.

Mineralogy of Bentonite and Related Clays

Most bentonites are composed of the clay mineral montmorillonite, but a few are characterized by the related mineral beidellite. Montmorillonite has also been identified from altered lithium-bearing pegmatites, beidellite from gouge clays in mineral veins, and a micaceous mineral that has the composition of halloysite from altered pegmatites and gouge clays. These minerals have different chemical compositions but resemble each other in being obviously crystalline and often rather coarsely crystalline; in possessing a platy, or micaceous habit and easy cleavage, and rather high birefringence. They resemble the micas in many ways and may sometimes be mistaken for them, and they differ in many ways from kaolinite and halloysite. Beidellite and the micaceous mineral corresponding to halloysite have somewhat higher indices of refraction and higher birefringence than montmorillonite but all are characterized by a high water content. They all possess marked adsorptive powers which appear to be more dependent upon physical form than chemical composition. Beidellite and montmorillonite have heretofore been grouped with leverrierite and the other mineral has not been differentiated from halloysite. Leverrierite is imperfectly known and its place in the group is undertermined.

Chemical Composition

The crystalline clay minerals, despite their fineness of grain, are characterized by platy structure and eminent basal cleavage and have many of the physical properties of the mica division, which includes the true micas and chlorites as well as many poorly known highly

[1] Edgar T. Wherry, *Jour. Mineralogical Soc. of Amer.*, **10**, 65 (1925).

hydrous silicates generally called hydromicas and vermiculites. Many of these are among the most difficult of all minerals to interpret chemically and even the best analyses made upon well-crystallized and pure material show wide variations in composition even though classified as a single mineral. Several complex theories have been put forward to explain the chemical constitution and account for the variation but none of these seems entirely satisfactory.

The clay minerals, being micaceous, might be expected to exhibit all the vagaries of composition found in the more coarsely crystallized micaceous minerals. The study of bentonite and some other related clays has, however, given results which apparently indicate that the clay minerals are few in number and that each is a single definite chemical compound of simple type rather than an isomorphous mixture of two or more dissimilar end-members. The pure clays that have been studied are composed of one of the following five distinct clay minerals. Two of these have been found in the bentonites and the other three have been encountered in non-bentonitic clays. These five minerals may be enumerated as follows:

Name	Chemical Composition	Physical form	Crystal system
1. Montmorillonite	$(Mg,Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot nH_2O$	micaceous	orthohombic?
2. Beidellite	$Al_2O_3 \cdot 3SiO_2 \cdot nH_2O$	micaceous	orthohombic?
3. Micaceous halloysite	$Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$	micaceous	orthohombic?
4. Halloysite	$Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$	amorphous or submicroscopical crystalline	unknown
5. Kaolinite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	platy crystalline	monoclinic

The analyses of bentonite hitherto published showed great variations in composition, particularly in the ratio of alumina to silica. In part this seemed to be the result of poor analytical work but it was apparently largely due to the presence of detrital grains of foreign material which were not removed from the samples prior to analysis. The purest and cleanest bentonites showed a distinct similarity to each other in composition and approached the clay mineral montmorillonite. They differed from the original analyses of montmorillonite, however, in the almost invariable presence of more or less of bivalent bases, notably magnesia with less lime. The analyses by the present writers were all made upon carefully selected or purified material. The method of purification consisted in thoroughly disintegrating the clay in water and decanting the material which remained in suspension various lengths of time. In this manner the clay substance could be rather uniformly graded and several crops of clay grains secured that were practically free from the impurities, which settled to the bottom of the vessel together with the coarser particles of the clay mineral. This method can be applied to

bentonites for the impurities are igneous rock phenocrysts that are larger and more uniform than the impurities in residual or detrital clays. In several cases coarser and finer samples obtained from the same clay were analyzed separately and it was found that, when free from foreign materials, these did not differ appreciably from each other in composition.

The majority of the bentonite analyses made upon pure material agreed with each other in giving a formula similar to that for montmorillonite but slightly higher in silica ratio and containing approximately one molecule of bivalent bases. A portion of the type material of montmorillonite from Montmorillon, France, was obtained for comparison by exchange from Prof. Lacroix of Paris. This was reanalyzed and found to give results closely comparable with those of the American bentonites. The French montmorillonite does not show a definite volcanic ash structure and it probably is not bentonitic. Montmorillonite can, however, form by other processes than those producing bentonite. Wells[1] has analyzed a montmorillonite occurring as an alteration product of spodumene in pegmatite at Branchville, Conn., and the present writers have examined a clay of similar origin from Embudo, New Mexico, which also proved to be montmorillonite.

In the following there are presented a selection of analyses of bentonites:

TABLE I

ANALYSES OF BENTONITE (MONTMORILLONITE)

	1	2	3	4	5	6	7
SiO_2	51.10	48.80	50.30	49.56	51.56	54.46	57.28
TiO_2	——	——	——	.40	.78	.80	.50
Al_2O_3	15.40	21.08	15.96	15.08	13.42	16.84	16.04
Fe_2O_3	4.50	.92	.86	3.44	3.22	3.36	4.02
MnO	——	——	——	.01	——	——	——
CaO	5.20	1.36	1.24	1.08	2.04	3.20	1.72
MgO	3.80	4.84	6.53	7.84	4.94	4.84	3.28
K_2O	1.50	——	.45	——	.38	——	——
Na_2O		——	1.19	——	.24	——	——
H_2O	17.10	20.92	23.61	22.96	23.46	16.10	17.10
Total	98.50	97.92	100.24	100.37	100.04	99.60	99.94

1. Bentonite, selected crude, Ardmore, S. Dak. Anal. by E. T. Wherry, *Jour. Wash. Acad. Sci.*, **7**, 580 (1917).
2. Bentonite, Ardmore, S. Dak. Fine portion. Purified by Clarence S. Ross, Earl V. Shannon, analyst.
3. Bentonite (otaylite) crude selected white material, near Otay, San Diego Co Calif. J. E. Whitfield, analyst.

[1] H. L. Wells, *Amer. Jour. Sci.*, **20**, 283 (1880).

4. Bentonite (otaylite) crude selected pink material, near Otay, San Diego Co., Calif. Earl V. Shannon, analyst.
5. Bentonite, pink friable matrix of bentonite tuff. Three miles north of the east end of the Tierra Amarilla Grant, New Mexico. Purified by Clarence S. Ross. Earl V. Shannon, analyst.
6. Bentonite, pink friable matrix of bentonite tuff. Conejos Quadrangle, Colorado. Separated and purified by Clarence S. Ross. Earl V. Shannon, analyst.
7. Bentonite. Sent from Boise, Idaho, by Edward Schwerd. Contained abundant calcite which was removed with dilute hydrochloric acid. Earl V. Shannon, analyst.

TABLE I (*continued*)

ANALYSES OF BENTONITE (MONTMORILLONITE)

	8	9	10	11	12
SiO_2	50.33	49.20	52.08	56.20	50.28
Al_2O_3	16.42	17.60	18.20	13.20	20.00
Fe_2O_3	2.42	1.60	2.88	5.08	4.00
CaO	1.39	1.52	2.28	1.60	1.08
MgO	4.10	5.08	4.48	2.92	4.60
K_2O	1.00	——	——	——	——
Na_2O	.12	——	——	——	——
H_2O	23.95	25.52	20.80	20.32	19.60
Total	99.85	100.52	100.72	99.32	99.56

8. Bentonite. Sent in by G. A. Martin of Maricopa, Kern County, Calif. Selected crude. Earl V. Shannon, analyst.
9. Bentonite. Fort Steele, Wyoming. Purified by Clarence S. Ross. Earl V. Shannon, analyst.
10. Bentonite. Wisconsin, Texas. Purified by Clarence S. Ross. Earl V. Shannon, analyst.
11. Bentonite. Quilchena, B. C. Furnished by Hugh Spence, of Mines Branch Geol. Survey of Canada. Purified by Clarence S. Ross.
12. Bentonite. Sent in by California Master Products Corp., of Los Angeles, Calif. Purified by Clarence S. Ross. Earl V. Shannon, analyst.

For purposes of comparison the analyses of montmorillonite of non-bentonitic origin are given in Table II. The agreement between the analyses of the bentonites is remarkably good especially when it is borne in mind that the materials are of detrital origin, are exceedingly fine-grained and high in absorptive and adsorptive capacity. The presence in approximately constant amount of bivalent bases, principally magnesia with less lime, has led to the conclusion that these are an essential part of the mineral molecule. Consequently the present writers have written the formula for this mineral

$$R''O \cdot R''_2O_3 \cdot 5SiO_2 \cdot 5\text{–}7H_2O$$

Where the bivalent bases fail in a few cases the similarity can still be expressed by writing one molecule of water, basic and replaceable thus:

$$(H_2,\ Mg,\ Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot 5\text{–}7H_2O$$

Heretofore it has been customary to consider the magnesia and lime present in these clays to be adsorbed or present as extraneous impurities but this interpretation seems no longer tenable.

The analyses given in Tables I and II seem to show conclusively that the clay mineral of these bentonites is identical with montmorillonite and they clearly support the formula here proposed. The Attapulgus, Georgia, fullers' earth likewise conforms with this formula and it is interesting to draw attention to the fact that the formula derived by Fersman[1] for a Russian fullers' earth is the same.

TABLE II

COMPOSITION OF MONTMORILLONITE

	13	14	15	16	17	18
SiO_2	49.40	48.60	51.20	48.24	51.28	50.60
Al_2O_3	19.70	20.03	22.14	22.32	10.56	17.23
Fe_2O_3	.80	1.25	——	.36	6.76	——
CaO	1.50	1.72	3.72	2.04	1.44	3.21
MgO	.27	5.24	3.53	6.64	10.40	4.56
MnO	——	.16	.18	——	——	——
$(K, Na)_2O$	1.50	——	.56	——	——	——
H_2O	25.67	21.52	17.08	20.84	20.28	24.32
P_2O_5	——	——	1.42	——	——	——
Total	98.84	98.52	99.83	100.54	100.72	100.00

13. Montmorillonite, Montmorillon, France. Analysis by Salvetat; Dana System of Mineralogy, p. 690.
14. Montmorillonite, Montmorillon, France. Earl V. Shannon, analyst.
15. Montmorillonite from pegmatite, Branchville, Conn. H. L. Wells, analyst. Dana System of Mineralogy, p. 690.
16. Montmorillonite from pegmatite, Embudo, New Mexico. Collected by F. L. Hess. Earl V. Shannon, analyst.
17. Fullers' earth, Attapulgus, Georgia. Purified by Clarence S. Ross. Earl V. Shannon, analyst.
18. Montmorillonite. Theoretical composition to satisfy the formula $(Mg, Ca)O \cdot Al_2O_3 \cdot 5SiO_2 \cdot 8H_2O$, with MgO : CaO present in the ratio of 2 to 1.

The analyses in the two preceding tables show some variation, but it will be seen that, aside from minor deviations, the proportions of bivalent bases, silica, and trivalent bases, alumina plus ferric iron, is decidedly constant. The essential constituent of greatest variability is the water which, while always large in amount, varies from 16.10% to 25.67%. The behavior of the water content of this mineral is of especial interest and has given basis for some very instructive specula-

[1] A. E. Fersman, *Revue de Geologic*, **5**, 98 (1919).

tion as to the manner in which the moisture is held or combined. The above analyses were in all cases made on air-dried material, that is, material which had been exposed in powdered form to the room or laboratory atmosphere until all of the excess moisture had dried off. The amount of water held by a given sample varies with the temperature and humidity of the surrounding atmosphere so that the same sample shows very appreciable differences in the amount of water when analyzed on different days if there is much difference in the relative humidity. A large part of the water is driven off at a temperature of 120°C, and much is lost at room temperatures in a dessicator over sulphuric acid and calcium chloride. Samples which have been dried to constant weight at 120° or possibly somewhat higher and have lost upwards of 12% of moisture, regain this in a few hours when allowed to stand exposed to the air of the room. The temperature of 110°C is without any significance whatever in the dehydration of these materials and, when the temperature is increased a few degrees, samples which have been brought to constant weight, lose additional water. The behavior of this water has not been fully investigated and more detailed study is planned. The behavior of two samples is tabulated below:

Loss of Water by Montmorillonite Clays

	1 Montmorillonite (France)	2 Otaylite (California)
100°C	11.88%	14.28%
140°C	2.00	1.48
450°C	2.64	2.44
Red heat	5.00	4.76
Total	21.52	22.96

The clays were heated until they had reached constant weight at each temperature. When samples which had been brought to constant weight at 140° were allowed to stand overnight in air they gave the following results:

	1 Montmorillonite (France)	2 Otaylite (California)
Lost at 140°	13.88	15.76
Regained overnight	13.88	11.56

This large amount of water which is so easily lost and regained seems to be without visible effect upon the optical properties of the mineral. From the above table it will be seen that only 5% or less of water is held by the mineral above 450°. This is a distinct difference from kaolin, halloysite, and the other clay tabulated above with the compo-

sition of halloysite, all of which retain water molecularly equivalent to the silica to a red heat.

The water content is subject to such variation under varying conditions that the exact statement of it in the formula is not practicable. The variation seems to be at least from 5 to 8 H_2O in the formula given for montmorillonite. The behavior of the water, the ease with which it is lost and regained and the fact that the physical properties of the mineral are not changed by the driving off of a large part of the water, has led the writers to the conclusion that this water is in large part adsorbed and not an essential integral part of the chemical molecule making up the mineral. This tendency to adsorb such large amounts of water is doubtless a function of the physical structure of the material which, being extremely finely micaceous gives relatively enormous surface area. This is one of the so-called colloidal properties which has led to bentonite being considered a colloid.

Two clays of bentonitic habit and appearance which were examined were found to have the same alumina-silica ratio and about the same amount of bivalent bases as the above but they differed in the presence of nearly 6% of potash and in having very considerably less water than the average under the same conditions. The analyses of these are given below as Table III:

TABLE III

ANALYSES OF POTASH BEARING BENTONITES

	19	20
SiO_2	55.64	53.12
Al_2O_3	16.80	18.72
Fe_2O_3	2.68	1.12
CaO	1.80	1.40
MgO	8.88	6.92
K_2O	5.16	5.72
Na_2O	.04	trace
H_2O	9.72	12.04
Total	98.72	99.04

19. Bentonite, "soap clay" from Suifu, China. Collected by D. C. Graham, purified by Clarence S. Ross. Analyzed by E. V. Shannon.
20. Bentonite. High Bridge, Kentucky. Coll. Charles Butts. Purified by Clarence S. Ross, Analyzed by Earl V. Shannon.

These clays with their high potash and low water contents introduce a very interesting question of the relationship of water to potash. The variation of the water from day to day is shown above in comparison with typical montmorillonite. Aside from the potash content both of these agree reasonably well with the chemical formula given for montmorillonite. The potash, figured out to molecular ratio, is not sufficient

in amount to deserve place in the formula. The most striking thing about the presence of the potash is that total water varies inversely with the alkalis, one weight per cent of potash being approximately equal to two weight per cent of water. This ratio seems to hold good also for examples of these clays which contain smaller amounts of alkalis. This ratio bears no relation to the molecular weights of water and potash. It seems most reasonable to conclude that the potash, like the major part of the water, is adsorbed. Furthermore it appears that one part of adsorbed potash displaces approximately two parts of adsorbed water. The potash could not be extracted from the Kentucky material with hydrochloric acid.

Selective adsorption of potash without corresponding adsorption of soda has been recognized as a property of soils for some time but the adsorption was credited to the "soil colloid." Chemists interested in the search for a commercial potash supply in this country were long puzzled to account for the almost total absence of potash from the salt deposits of the closed desert basins. It was obvious that potash had been delivered to these basins in amount equal to or greater than the soda. It finally became apparent that the potash had been adsorbed by the muds whereas the soda had remained in the solutions. To this selective adsorption of potash by clays having "colloidal" adsorptive properties can be credited the fact that the ocean is salty from sodium chloride rather than a mixture of the chlorides of sodium and potassium.

Beidellite

A single occurrence of clay of unquestionably bentonitic structure and origin failed signally to show an agreement with the others, both in alumina to silica ratio and in the relative amount of bivalent bases. This clay, from Mine Creek near Nashville, Howard County, Arkansas, cannot be identified with montmorillonite although having many physical properties in common with that mineral. It does agree, however, with certain gouge clays which have been called leverrierite,[1] and later[2] have been given the new name beidellite.[3] The agreement of the Arkansas bentonite with beidellite is shown by the analyses of Table IV.

This mineral beidellite agrees very well with the formula $Al_2O_3 \cdot 3SiO_2 \cdot 4H_2O$ the bivalent bases being in sufficiently small quantity to be disregarded in the formula. The water content is similar to that of montmorillonite and behaves in an identical manner.

---

[1] E. S. Larsen, and E. T. Wherry, *Jour. Wash. Acad. Sci.*, **7**, 208–17 (1917).
[2] E. S Larsen, and E. T. Wherry, *Jour. Wash. Acad. Sci.*, **15**, 465 (1925).
[3] Clarence S. Ross, and Earl V. Shannon, *Jour. Wash. Acad. Sci.*, **15**, 467 (1925).

TABLE IV

ANALYSES OF BEIDELLITE

	21	22	23	24	25	26
SiO_2	45.52	45.12	47.28	45.32	46.06	50.85
TiO_2	——	——	——	——	.84	——
Al_2O_3	27.52	28.24	20.27	27.84	12.22	28.81
Fe_2O_3	2.80	4.12	8.68	.80	18.54	——
FeO	——	——	——	——	.28	——
CaO	.52	.88	2.75	2.76	1.66	——
MgO	3.00	2.32	.70	.16	1.62	——
K_2O	——	——	trace	.12	——	——
Na_2O	——	——	.97	.10	——	——
H_2O	19.60	18.72	19.72	22.64	17.26	20.34
Total	98.96	99.40	100.37	99.64	98.48	100.00

21. Bentonite. Mine Creek, near Nashville, Howard County, Arkansas. Fine separation product. Purified by Clarence S. Ross. E. V. Shannon, analyst.
22. Bentonite, same, coarser product.
23. Beidellite, "leverrierite" gouge clay from Beidell, Sagauche County, Colo. E. S. Larsen and E. T. Wherry, *Jour. Wash. Acad. Sci.*, **7**, 208–17 (1917).
24. Beidellite, "leverrierite" gouge clay, Black Jack vein, Carson Dist., Owyhee County, Idaho. E. V. Shannon, *Proc. U. S. Nat. Museum*, **62**, Art. 15 (1923).
25. Iron-rich beidellite; Spokane, Washington.
26. Theoretical alumina end member to satisfy $Al_2O_3 \cdot 3SiO_2 \cdot 4H_2O$.

One other crystalline finely micaceous clay of high water content has been encountered in the course of the present study. This is a snow-white rather hard clay from Washoe, Nevada. It is slickensided and may be a gouge clay. It probably is not a bentonite. The analysis is given below together with Schaller's analysis of the pink clay from the lithium pegmatite of Pala, San Diego, California which is probably the same mineral.[1] The composition of these clays is that of halloysite but they exhibit the finely crystalline structure of the montmorillonite and beidellite before considered. The formula derived from the analyses can be stated as: $Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$. The clay from Nevada contains about $4\frac{1}{2}$ H_2O while that from California contains only $3H_2O$, the difference possibly being due to different conditions of the atmosphere at the time they were analyzed. One feature in which the white clay from Nevada differs from the montmorillonites and beidellites is that it retains 14% of water above 140°C. The constitutional water of kaolinite amounts to two molecules, the formula being written $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ or $H_4Al_2Si_2O_9$. Halloysite retains two molecules of constitutional water to a red heat so that its formula is commonly written as $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + nH_2O$. The latter formula equally well represents the clay from Washoe, Nevada.

[1] Waldemar T. Schaller. U. S. Geol. Surv., *Bull.* **262**, p. 121.

TABLE V

ANALYSES OF CLAY FROM NEVADA AND CALIFORNIA, COMPARED WITH HALLOYSITE.

	27	28	29	30
SiO_2	37.40	43.62	40.09	40.90
Al_2O_3	34.04	35.55	35.58	34.66
Fe_2O_3	1.08	.21	trace	——
CaO	.60	1.02	.77	——
MgO	.64	.19	trace	——
MnO	——	.26	——	——
Li_2O	——	.23	——	——
Na_2O	——	.19	.10	——
K_2O	——	.03	trace	——
H_2O	26.40	18.88	23.61	24.44
Total	100.16	100.18	100.15	100.00

27. White slickensided clay from Washoe, Nevada. Earl V. Shannon, analyst.
28. Pink clay from gem-bearing pegmatite, San Diego Co., Calif. Waldemar T. Schaller, Analyst. *Loc. cit.*
29. Halloysite, Wagon Wheel Gap, Colo. Edgar T. Wherry, analyst. E. S. Larsen and E. T. Wherry. *Loc. cit.*
30. Calculated composition to agree with formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ · plus 2Aq.

Optical Properties

The following table gives the optical properties of the clay minerals that have been described in this paper.

TABLE VI

OPTICAL PROPERTIES OF THE CLAY MINERALS

	α	β γ	$\gamma-\alpha$	$2v$	Optical Character
Montmorillonite from normal bentonites, analyzed[1]					
[1] The numbers correspond with the analyses in Table I, pp. 88 and 89.					
2 Ardmore, S. Dak.	1.495	1.520	.025		—
4 Otay, San Diego Co., Calif.	1.492	1.513	.021	16°-24°	—
5 Tierra Amarilla Grant, N. Mex.	1.51	1.53			—
8 Maricopa, Kern Co., Calif.	1.492	1.515	.023	15°-22°	—
9 Fort Steel, Wyo.	1.484	1.508	.024	13°-24°	—
10 Wisconsin, Texas	1.493	1.515	.022	7°-19°	—
11 Quilchena, B. C.	1.487	1.514	.027	18 ±	—
Montmorillonite from normal bentonites, analyzed.					
Rosedale, Alberta	1.492	1.514	.022	small	—
Rideout, Utah	1.478	1.500	.022	10°-16°	—
Montmorillonite from altered pegmatites[2]					
[2] The numbers correspond with the analyses in Table II, p. 90.					

14 Montmorillon, France	1.503	1.527	.024		—
16 Embuda, N. Mex.	1.594	1.517	.023		—
Montmorillonite from fullers' earth[2]					
17 Bainbridge, Ga.	1.512	1.535	.023	17°-25°	—
Montmorillonite from bentonite, with adsorbed potash[2]					
[2] The numbers correspond with the analyses in Table III, p. 92.					
19 Suifu, China	1.543	1.565	.022	12°-25°	—
20 High Bridge, Ky.	1.528	1.550	.022	15°-27	—
Beidellite from gouge clays and bentonite[4]					
[4] The numbers correspond with the analyses in Table IV, p. 94.					
21 Mine Creek, Nashville, Ark.	1.517	1.549	.032	16° ±	—
23 Beidell, Colo.	1.494	1.536	.042	small biaxial	—
24 Black Jack Vein, Owyhee Co., Idaho	1.488	1.527	.039	"	—
25 Spokane, Wash.	1.523	1.572	.051	"	—
Wagon Wheel Gap, Colo.	1.495	1.537	.042	"	—
Micaceous, crystalline "halloysite"[5]					
[5] The numbers correspond with the analyses in Table V, p. 95.					
27 Washoe, Nev.	1.540	1.550	.010	?	
28 San Diego Co., Calif.	1.495	1.518	.023	—	

The foregoing tables show that the montmorillonite from normal bentonites has indices of refraction that vary but little from the mean values that are $\alpha = 1.493$, β and $\gamma = 1.516$, and the montmorillonite from other sources shows nearly the same values. The potash-bearing bentonites are composed of montmorillonite with a higher indices of refraction since the water which tends to lower the indices has been displaced by potash. The beidellites are very likely to contain ferric iron which is present in varying proportions in all the samples analyzed. For this reason the indices of refraction are higher and more variable than in the montmorillonite, and the birefringence is also higher. The micaceous "halloysite" from San Diego, California, has optical properties that are very close to those of the other minerals described in this paper. The higher indices and lower birefringence of the clay from Washoe, Nevada, suggest that it may be a distinct mineral. The San Diego clay is believed to be distinct from halloysite though having the same chemical composition but it is possible that the Washoe clay is a true halloysite that happens to have visible crystallinity.

INFLUENCE OF COMPOSITION OF BODY AND GLAZE ON THE PHYSICAL PROPERTIES OF A TRUE PORCELAIN[1]

By Pyungtoo William Lee

Abstract

An effort to produce a higher quality of true porcelain at cones 10 to 12. Physical properties of body and glaze and their workabilities are observed. Tested for shrinkage, warpage, translucency, absorption and modulus of rupture.

Introduction

The purpose of this investigation is to obtain the possibility of producing a true porcelain of higher quality, chiefly, using domestic materials. The proper proportions and mixture of the different constituents and ingredients in the body and glaze have much to do with the quality of the ware. In solving the problem there are two things to be considered: the physical and chemical properties of their constituents, and their influences. This present investigation deals only with the physical properties and their influence.

The Layout of the Investigation

1. Raw Materials

The raw materials used in this investigation are as follows:

Canadian feldspar.....Pa. Feldspar Co.
Flint.....Ohio Silica Co.
English china clay.....Moore and Munger's M.W.M.
Florida kaolin.....Edgar Kaolin Co.
Whiting ($CaCO_3$).....Gilder's
Magnesium carbonate ($MgCO_3$)
Boric acid (H_3BO_4)

2. Preparation of Body

The three end members, (Nos. 1, 11, and 15) were thoroughly mixed by grinding in ball mills for 72 hours and screened through 150-mesh sieve. The other 12 members of the series were the combinations of the three end members. Two cups were cast from each member; then the slips were dried in the open air to the stage of plastic clay and used for jiggering cups and molding trial bars for modulus of rupture, absorption and translucency. The cups and trial pieces were dried to bone dryness in the gas heated drier and biscuited at cone 06. Necessary measurements for shrinkage, loss of weight and other observations were taken before they were glazed.

Glazing and Setting

The cups, both cast and jiggered, and two trial pieces for translucency and warpage were glazed with the following glaze at 20 ounces to a pint.

[1] A thesis presented for the degree of Master of Science, Ohio State University (1922).
Received November, 1925.

$$\left.\begin{array}{l} 0.19\ K_2O \\ 0.7225\ CaO \\ 0.025\ MgO \\ 0.025\ BaO \\ 0.0375\ ZnO \end{array}\right\} 0.7\ Al_2O_3 – 7.0\ SiO_2.$$

The cups and the trial pieces were dipped into the glaze with a slow motion. The thickness of the glaze was about $\frac{1}{32}$ inch. The glaze had a very little flowing action at the glost fire.

Placing in a Sagger and Kiln Setting The cups and bars (outside bottom of the cups and on side of the bars not glazed) were placed upon a sand bed in the sagger and the trial pieces for translucency and warpage were placed upon tiles in saggers.

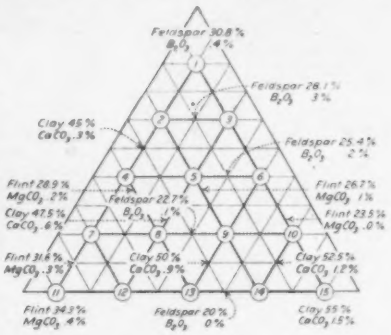


FIG. 1.—Shows the different bodies in a triaxial form and compositions of Series 4.

Glost Firing The total firing period was 26 hours. More excess air was used during the period of water-smoking. The dampers were left wide open from the beginning of the firing until the kiln was completely cooled.

Tests

The tests applied in this series were for shrinkage, loss in weight, cross breaking and modulus of rupture, absorption, warpage and translucency.

The whiteness of the color was observed on glazed and unglazed bodies both cast and jiggered. The results are as follows:

Color The order of color in its clearness and whiteness is as follows: 8, 7, 11, 12, 13, 4, 9, 14, 15, 2, 3, 6, 5, 10, 1. A difference of color noticed even on the same composition which was due to the variation of the temperature and the kiln atmosphere. It may be possible to improve the colors of all bodies by firing with greater excess of air throughout the firing period.

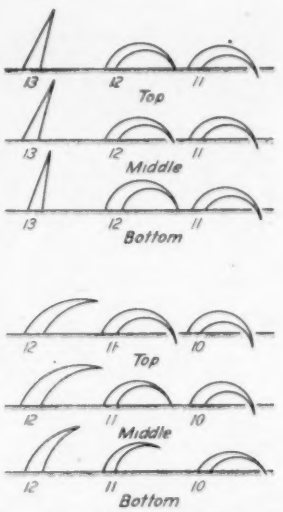


FIG. 2.—Observation of the cones. Cones outside of saggers shown above and those inside shown below.

Measurement of Shrinkage Only linear shrinkage was obtained from plastic to dry, dry to biscuit, and dry to glost. From these values the per cent of shrinkage, on dry bases, was calculated.

Measurement of Loss in Weight First the water content of each plastic body was determined, then the weights on dry bodies, biscuited bodies, and glost bodies measured from which the present loss in weights was calculated on a dry base.

Modulus of Rupture The unglazed and glost fired square bars were broken by Riehle Bros. T. M. Co. Cross Breaking Strength Machine. The length (L) between two supporting distances was 3 inches. This gave the value of cross breaking strength directly for a cross sectional area of the broken bars. From these values the modulus of rupture was calculated by using the formula

$$M=\frac{3PL}{2bd^2}.$$

P = weight required to break the bars
L = distance between supporters. (3 inches)
b = width of broken section,
d = depth of broken section.

These values were again interpolated for the value of one square inch.

Absorption Test The broken bars were weighed and boiled in water for over two hours, and then remained in water for more than 48 hours. These were again weighed and the per cent of absorption calculated by using the formula

$$P=\frac{W-w}{w}\times 100$$

where W = wet weight,
w = dry weight
P = per cent absorption.

Measurement of Warpage Two methods were employed for the measurement of warpage: One by observing the degree of warpage from cast and jiggered cups and another by measuring the height of the bending places of the trial pieces as shown in Fig. 3.

Measurement of Translucency

The translucency was measured by means of an electric light. At one end of a box was placed an electric light bulb. A tin plate was placed at one end of the box and in it was a hair crevice which transmitted the light. Tests were made by placing the trial pieces against the crevice and moving them from the thin to the thicker end. The line where the light ceased to be transmitted was noted and marked and then thickness of the body at this line was measured by a micrometer.

FIG. 3.

Comparisons

Numbers 8 and 7 are the best bodies and No. 8 has proved to be the best in working properties.

Comparing purity and whiteness of the colors with the American and French porcelains, Nos. 8 and 7 have proved superiority over American porcelain and No. 8 has approached very closely the best French porcelain.

FIG. 4.—Per cent shrinkage on dry base.

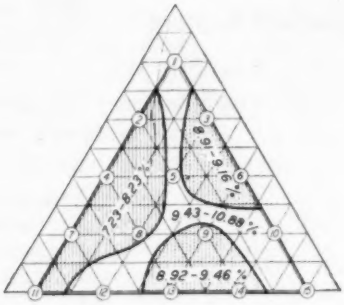


FIG. 5.—Per cent loss in weight on glost firing.

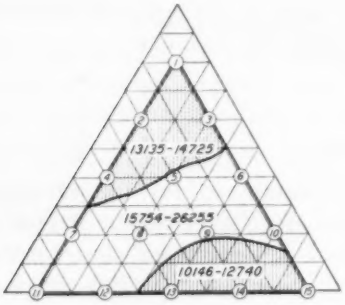


FIG. 6.—Modulus of rupture.

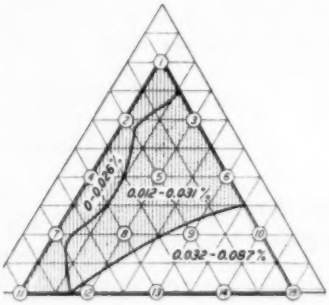


FIG. 7.—Per cent absorption

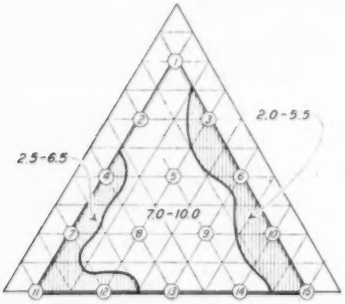


FIG. 8.—Warpage of Series 4.

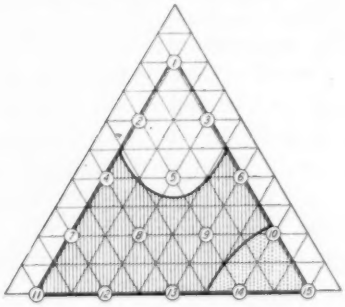


FIG. 9.—Translucency.[1] Scale $\frac{1}{100}''$

[1] Bodies 1, 2, 3, 5 are 12.00–12.40
Bodies 4, 7, 11, 8, 12, 6, 9, 13 are 11.18–11.23.
Bodies 10, 14, 15 are 11.20–11.90.

Conclusions

In this investigation the following general facts were observed:

1. The application of a glaze is better on jiggered than on cast bodies.

2. The warpage is always greater in the cast than in the jiggered bodies.

3. The translucency for the same composition is increased with the increase of temperature.

4. There is a temperature which produces the best color for a definite body. Below this point the color of the body will not fully develop and beyond it the color will be changed with other influences.

5. To obtain the best working conditions the total of alkaline earth fluxes must not be over 1%. If $MgCO_3$ is used to improve the color of the body it must not be more than 0.4%.

6. Vitrification is increased with the increase of feldspar and flint, and decrease of clay.

7. Translucency is increased with the increase of feldspar at the expense of flint and clay.

8. Loss in weight is increased with the increase of clay and decreased with the increase of flint.

9. Shrinkage is increased with the increase of feldspar and decreased with the increase of flint and clay.

10. The fusion point of any glaze can be lowered by long and fine grinding, but it will tend to increase the tendency to crazing if the coefficient of expansion of the body and glaze are not the same.

11. The zinc content in the glaze increases the white color but decreases the translucency and produces a rough surface.

In conclusion it is safe to say that No. 8 in the Series 4 which proved superior to the American porcelain and ranked close to the French met all conditions above normal that a true porcelain might require.

Bibilography

On Bodies

From *Collected Writings* of Herman A. Seger

"The Necessity of Homogeneity of Clay" **1**, pp. 33-35.

"The Value of Physical Property of a Clay," **1**, pp. 36-37.

"Mechanical Analysis of a Clay," **1**, pp. 41-44.

"Rules for Correcting Crazing and Shivering of a Glaze by Means of Changing Body Composition," **2**, p. 577.

"Composition of Some Hard Porcelains," **2**, 678-95.

From *Transactions of the American Ceramic Society*

S. G. Burt, "The Fineness of Flint in its Relation to the Manufacture of Pottery. Bodies," *Trans. Amer. Ceram. Soc.*, **3**, 17 (1901).

C. F. Binns, "The Birth of English Porcelain," *Trans. Amer. Ceram. Soc.* **3**, 142 (1901).

A. S. Watts, "The Composition of Porcelain for Electric Purposes," *Trans. Amer. Ceram. Soc.*, **4,** 86 (1902).

L. E. Barringer, "Influence of Magnesia on Clay," *Trans. Amer. Ceram. Soc.* **6,** 86 (1904).

E. P. Ogden, "The Relation between the Composition of a Porcelain Body and Its Toughness," *Trans. Amer. Ceram. Soc.*, **7,** 370 (1905).

C. E. Jackson, "Seger Porcelain with Materials Accessible to American Potters," *Trans. Amer. Ceram. Soc.*, **8,** 114 (1906).

A. S. Watts, "The Coefficient of Linear Expansion of Porcelain," *Trans. Amer. Ceram. Soc.*, **11,** 84 (1909).

Charles Weelans, "Distinction in the Grading of White Ware in Commerce—Particularly of Plumber's Ware," *Trans. Amer. Ceram. Soc.*, **13,** 306 (1911).

Ross C. Purdy, "Range in Composition of Glazed White Ware Body Made from Clay, Feldspar and Flint," *Trans. Amer. Ceram. Soc.*, **13,** 86 (1911).

J. W. Wright and S. J. Sewell, "Some Physical Properties of American Commercial Porcelain Bodies," *Trans. Amer. Ceram. Soc.*, **2,** 282 (1900).

F. H. Riddle, "Relation between the Composition and the Thermal Expansivity of Porcelain," *Trans. Amer. Ceram. Soc.*, **2,** 804 (1900).

A. V. Bleininger and W. W. McDanel, "The Use of American Raw Materials in the Manufacture of White Ware Pottery," *Trans. Amer. Ceram. Soc.*, **3,** 134, 997 (1901).

From *Transactions of Ceramic Society* (England)

S. Burt, "Seger's Law for Coefficient," *Trans. Ceram. Soc.*, (Eng.) **2,** 31 (1902).

J. W. Mellor, "Some Notes on Hard Feldspathic Porcelain," *Trans. Ceram. Soc.* (Eng.)., **14,** 176 (1914).

From Other Literature

C. C. Lin, "A Study of High Fire Porcelain," A Thesis, (1919).

On Glazes

From *Collected Writings* of Herman A. Seger

"Glaze Defect and Causes," **2**–559.

"To Change the Fusibility of a Glaze," **2**–571.

"Rules for Correcting Crazing and Shivering," **2**–577.

"Decoration of Japanese and Seger Porcelain," **2**–708–58.

From *Transactions American Ceramic Society*

Charles F. Binns, "The Birth of English Porcelain," *Trans. Amer. Ceram. Soc.*, **7,** 76 (1905).

A. S. Watts, "The Action of Different Forms of Calcium as a Flux in Porcelain Manufacture," *Trans. Amer. Ceram. Soc.*, **10,** 263 (1908).

Ross C. Purdy, "Seger's Rule for Correction of Glaze Defects by Changing the Body," *Trans. Amer. Ceram. Soc.*, **13,** 157 (1911).

Ross C. Purdy, "Porcelain Glazes," *Trans. Amer. Ceram. Soc.*, **13,** 550.

R. T. Stull, "Influence of Variable Silica and Alumina on Porcelain Glazes of Content RO," *Trans. Amer. Ceram. Soc.*, **14,** 62 (1912).

Herman Harkort, "A Method of Testing Crazing of White Ware," *Trans. Amer. Ceram. Soc.*, **15,** 368 (1913).

R. T. Stull and W. L. Howat, "Deformation Temperatures of Some Porcelain Glazes," *Trans. Amer. Ceram. Soc.*, **14,** 454 (1912).

From *Transactions of the Ceramic Society (English)*

A. Heath, "A Few Notes on Fineness of Particles in Glazes," *Trans. Ceram. Soc.*, (Eng.)., **4,** 42 (1904).

A. I. Hopkins, "Glaze Construction Volume Relationship," *Trans. Amer. Ceram. Soc.* (Eng.), **8,** 120 (1908).

J. W. Mellor, "Some Notes on Hard Feldspathic Porcelain," *Trans. Amer. Ceram. Soc.*, **10,** 124 (1910).

From Other Literature

Y. Y. Wong, "A Porcelain Glaze Maturing at Cone 11," A Thesis, (1920).

INFLUENCE OF Fe_2O_3 AND TiO_2 ON PURE CLAYS[1]

By Adolph Harmon Kuechler

Abstract

In this thesis, the effect of small additions of TiO_2 and Fe_2O_3 on the fusion temperature of kaolin and fire clay is investigated.

Introduction

In this thesis, the effect of small additions of TiO_2 and Fe_2O_3 on the fusion temperature of kaolin and fire clay are investigated. The object is to determine the action of Fe_2O_3 and TiO_2, in clays and to secure evidence on whether chemical composition or mineral classification shall be made the basis for the estimation of the refractoriness of clays.

Effect of Titanium

Several ceramic phenomena have been accredited to the function of titanium in clays. It has been shown that it exerts a fluxing influence, but to what extent and in what manner has never been definitely determined.

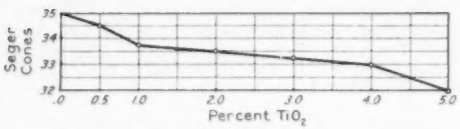


Fig. 1.—Kaolin and titanium oxide by H. Ries.

H. Ries[2] has shown that even small amounts of titanium lower the refractoriness of a clay. In his experiments a white firing sedimentary clay fusing at cone 35 was mixed with amounts of ½, 1, 2, 3, 4, and 5% of very finely ground rutile. These mixtures were then formed into small cones and tested in the Deville furnace. The results of these tests are shown in Fig. 1.

Rieke[3] made up a series of mixtures of chemically pure TiO_2 and Zettlitz kaolin, determining their fusion points with the following results:

Kaolin Per cent	TiO_2 Per cent	Cone of fusion	Kaolin Per cen	TiO_2 Per cent	Cone of fusion
100	0	35	40	60	20
90	10	30	30	70	+20
80	20	−26	20	80	−26
70	30	20	10	90	26
60	40	−20	0	100	−27
50	50	19–20			

[1] A thesis presented for the degree of Bachelor of Ceramic Engineering, Ohio State University, (1924).

[2] *N. J. Geol. Surv.*, **6**, 71 (1904).

[3] *Sprechsaal*, **41**, 406 (1908).

C. K. Bryce studied the effect of TiO_2 on the pyrometric value of a clay as a thesis at Ohio State University in 1909. He found in using Georgia kaolin, Laclede-Christy fire clay and Standard ruby rutile that within the limits of the investigation titanium acts as a neutral flux. Within the limits of the experiment, no eutectic points were observed in the melting point curve and no apparent chemical changes. See Fig. 2.

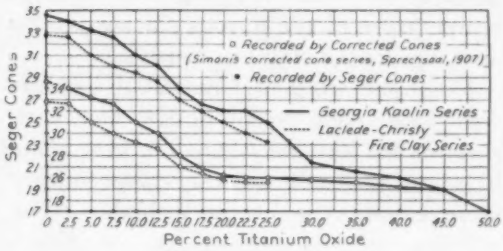


FIG. 2.—Melting points of TiO_2 and clay mixtures.

Effect of Iron Oxide

Dr. Ries found that iron oxide is a fluxing impurity, lowering the fusion of a clay, and this effect will be more pronounced if the iron is in a ferrous condition or if silica is present. A low iron content is, therefore, desirable in refractory clays, and the average of a number of analyses of these shows it to be 1.3%. Brick clays, which are usually easily fusible, contain from 3 to 7% of iron oxide.

A. V. Bleininger and G. H. Brown[1] state that iron oxide in the finely divided condition is one of the most potent fluxes. When present in the form of coarser particles, occurring as siderite or pyrite, its effect is not so marked, since evidently the action is proportional to the surface factor, *i.e.*, the fineness.

At the high temperatures to which refractories are exposed the ferric oxide of the clay dissociates to one of its lower forms. According to Le Chatelier[2] this dissociation takes place at 1300°, according to White and Taylor at 1200°, and to P. T. Walden[3] at 1350°C. The last named value represents probably the most reliable results. At this temperature the dissociation pressure reaches 160 mm., which is equal to the oxygen pressure of the air. Ferric oxide hence cannot exist above this temperature. It does not seem probable that the magnetic oxide $3Fe_2O_3 = 2Fe_3O_4 + O$ would persist at these high temperatures in contact with a silicate of the first clay type. The reduction under these conditions very likely results in FeO, which at the temperatures involved would at once combine with silica to form ferrous silicate. This change is hastened by the reducing conditions which usually prevail in the atmosphere of firebrick kilns. Larger lumps of iron oxide embedded

[1] U. S. Bur. Stand. *Tech. Paper*, **7**.
[2] "High Temperature Measurements," p. 246
[3] *Jour. Amer. Chem. Soc.* **30**, 1350

in the clay mass may consist in part of ferro-ferric and ferrous oxide, but the finely divided oxide may be assumed to be only FeO. Reaction between FeO and SiO_2 progresses rapidly, and owing to the low fusion temperature of the ferrous silicate the resulting slag is very corrosive and attacks the clay vigorously.

From the work of Cramer[1] it appears that iron oxide is an active flux with clays of the formula Al_2O_3–2.5 SiO_2, while it is less active in fire clays approaching more closely the kaolin formula. The addition of 0.2 equivalents of Fe_2O_3 sufficed to lower the softening temperature of a clay mixture of the formula Al_2O_3–2.5SiO_2 from cones 34 to 27.

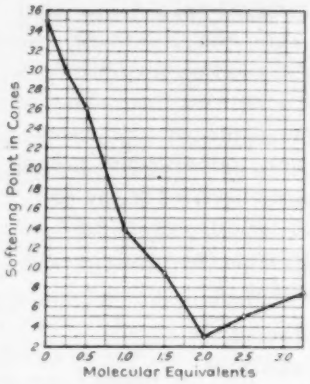


FIG. 3.—Effect of additions of FeO to Al_2O_3–2SiO_2.

The viscosity of ferrous silicates is quite low, as has been shown by Greiner, while ferric oxide acts in the opposite direction and increases the viscosity of silicate fusions. The softening temperatures given by Hoffman[2] for various ferrous silicates are as follows:

4 FeO–SiO_2.....1280°C	2 FeO–SiO_2.....1270
3 FeO–SiO_2.....1220	3 FeO–2 SiO_2....1140
4 FeO–SiO_2.....1120	

Figure 3 gives the results obtained by Rieke[3] on the fluxing action of FeO in a mixture of Al_2O_3–2 SiO_2.

Materials Used The materials used are: Florida kaolin, having the following composition:

Loss on ignition	14.86	TiO_2	.10
SiO_2	45.67	MgO	.05
Al_2O_3	38.45	K_2O	.06
Fe_2O_3	.75		
			99.94

Fe_2O_3, containing 97.8% iron ore and 2.2% impurities.
TiO_2, (finely ground rutile) manufactured by the American Rutile Co.
Fire clay with the following analysis:[4]

---

[1] "Wirkung der Flussmittel in Tonen." *Tonind. Ztg.*, No. 40-41 (1895).
[2] *Trans. Amer. Inst. Min. Eng.*, p. 682 (1899).
[3] *Sprechsaal*, p. 231 (1910).
[4] From Kier Fire Brick Co.

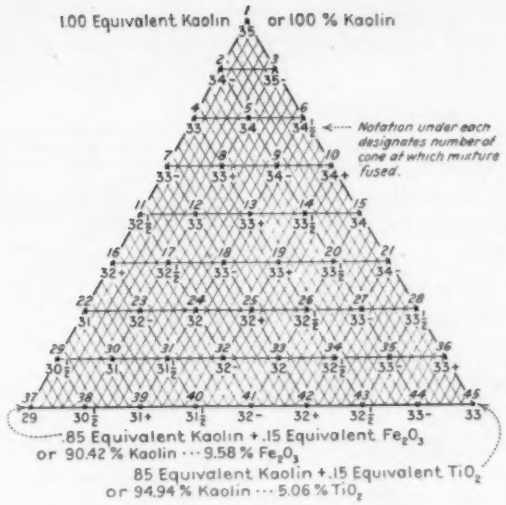

1.00 Equivalent Kaolin or 100 % Kaolin
Notation under each designates number of cone at which mixture fused.
.85 Equivalent Kaolin + .15 Equivalent Fe_2O_3
or 90.42 % Kaolin ··· 9.58 % Fe_2O_3
.85 Equivalent Kaolin + .15 Equivalent TiO_2
or 94.94 % Kaolin ··· 5.06 % TiO_2

FIG. 4.—Presenting data on fusion temperatures of kaolin Fe_2O_3–TiO_2 mixtures.

Ign. Loss	13.52%
SiO_2	43.10
Al_2O_3	38.94
Fe_2O_3	1.74
TiO_2	2.80
CaO	0.16
MgO	0.08
Alkalis	0.19
	100.53

Materials for cone plaques:

	Per cent
Calcined bauxite	50
Calcined Georgia kaolin	25
Florida kaolin	25

The molecular formula of the Florida kaolin is:

$$\left.\begin{matrix} 0.0016 & K_2O \\ 0.0032 & MgO \\ 0.0032 & TiO_2 \end{matrix}\right\} \left.\begin{matrix} 1.00 & Al_2O_3 \\ 0.0125 & Fe_2O_3 \end{matrix}\right\} \left.\begin{matrix} 2.013 & SiO_2 \\ 2.196 & H_2O \end{matrix}\right.$$

Eq. Wt. 265.6

The molecular formula and equivalent weight of the fire clay is:

$$\left.\begin{matrix} 0.008 & CaO \\ 0.005 & MgO \\ 0.092 & TiO_2 \\ 0.005 & Alkalis \end{matrix}\right\} \left.\begin{matrix} 1.000 & Al_2O_3 \\ 0.029 & Fe_2O_3 \end{matrix}\right\} \left.\begin{matrix} 1.796 & SiO_2 \\ 1.972 & H_2O \end{matrix}\right.$$

Eq. Weight = 259.1

The composition for each point on the triaxial, Fig. 4 is next determined.

Point 1 consists of 1.0 equivalents of Florida kaolin.

Point 37 consists of:

.85 equivalents of Florida kaolin or	265.64 = 225.50
.15 equivalents of Fe_2O_3 or	159.60 = 23.93
	249.43

and since 100 grams are to be made up for each point,

$$\frac{225.50}{249.43} \times 100 = 90.42 \text{ grams kaolin.}$$

(37) will have $\frac{23.39}{249.43} \times 100 = 9.58$ grams Fe_2O_3.

The mixtures for all the different points on the triaxial were determined in this manner.

The materials, after being weighed out, were thoroughly dry ground and mixed with a mortar and pestle.

The materials were ground to pass a 80-mesh screen.

After adding sufficient water to give the mixture the best working qualities, cones $1\frac{1}{8}$ inches in length were formed.

The cones were held in the plaques with calcined Al_2O_3, each plaque holding seven cones.

About one and one-half hours were required for a firing.

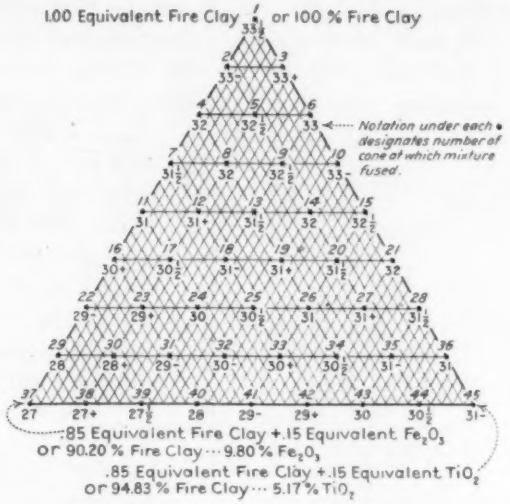

1.00 Equivalent Fire Clay or 100 % Fire Clay
Notation under each designates number of cone at which mixture fused.
.85 Equivalent Fire Clay +.15 Equivalent Fe_2O_3
or 90.20 % Fire Clay ··· 9.80 % Fe_2O_3
.85 Equivalent Fire Clay +.15 Equivalent TiO_2
or 94.83 % Fire Clay ··· 5.17 % TiO_2

FIG. 5.—Presenting data on fusion temperatures of fire clay Fe_2O_3–TiO_2 mixtures.

Results

The binary graph containing Fe_2O_3 additions (Fig. 6) tends toward a straight line. Iron is very susceptible to firing conditions, *i.e.*, ferrous iron is more of a flux than ferric iron, and this seems to account for the irregularities. Approximately 10% of Fe_2O_3 lowers the fusion temperature of kaolin and fire clay 6 and $6\frac{1}{2}$ cones respectively.

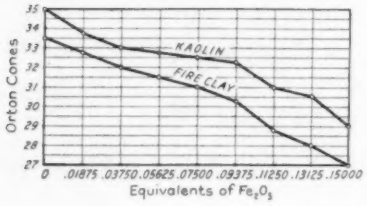


FIG. 6.

The binary graph containing TiO_2 additions (Fig. 7) is a straight line in the case of kaolin but is a little irregular in the case of the fire clay. The fluxing action of the iron content of the fire clay seems to account for this irregularity. About 5% TiO_2 lowers the fusion temperature of the kaolin and fire clay 2 and 3 cones respectively.

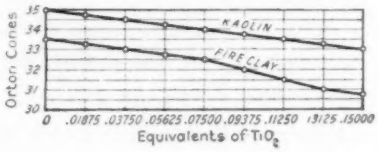


FIG. 7.

The binary graph containing Fe_2O_3 additions (Fig. 8) is merely interesting in that no eutectic forms. Again, in this case, the graphs tend toward a straight line.

Conclusions

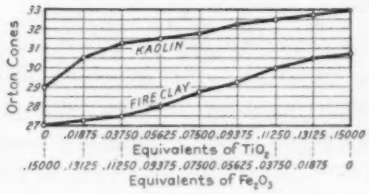


FIG. 8.

The results seem to indicate that there is about 6 to 6½ cones lowering of deformation period with the addition of about 10% Fe_2O_3, also that there is a deformation of 2 to 3 cones for an addition of about 5% TiO_2. The fluxing action of the Fe_2O_3 and TiO_2 appear to be about the same on a percentage basis.

This study failed to reveal an eutectic. (See Figs. 4 and 5.)

ELIMINATION OF LIMESTONE FROM CLAY[1]

By Roy A. Horning

Abstract

A successfully tried method of stone elimination is described.

Introduction

In this problem, it is well to take into consideration (1) What percentage of limestone is present, (2) The physical nature of stone and clay and (3) What effect will finely ground limestone have on the clay in question when distributed through the mass. Where the percentage of limestone is high the problem becomes very difficult, but if the percentage is not too great it may be attacked in several ways.

Many schemes have been devised for the removal of limestone and some have been fairly successful. Where the clay is friable and fairly dry, rubber covered rolls and screens are very good. This process will eliminate about 95% of the stone if it is not too hard. However, with this method it is not practical to screen some clays finer than $\frac{1}{4}$ inch and this often is not fine enough. This method has some merit, but its chief defect is that it will not work the year around, especially when the clay is wet.

The physical nature of both the stone and clay really determines the type of process that can be used. Obviously a shale would have to be treated differently from a clay.

Method Used at Lancaster

We assume that any stone is objectionable and should be eliminated if possible. Our trials of many schemes have shown that a certain per cent can be eliminated but that it is doubtful if 100% elimination is possible.

When all the elimination that is practical has been accomplished, fine grinding is used, reducing the percentage that is left to a very fine powder, thus rendering it less harmful.

The details of the process is given as follows:

1. Care is exercised in the clay pit as far as is possible to avoid the stone.

2. When the cars are dumped into the feeder the clay is retained on a steel grid temporarily, the clay being worked through the grid and the larger stones thrown out by hand. The smaller stones go through to the grinder.

---

[1] Recd. Dec. 31, 1925.

See Bibliography of literature on pebbles removal by Fred T. Heath, *Bull. Amer. Ceram. Soc.*, **4** [4] 165-88 (1925).

3. The clay and smaller stones are fed into a pair of conical rolls. One roll is threaded and one roll is plain. The rolls are spaced about $\frac{1}{4}$ inch apart. Practically all stones larger than one inch which constitute about 85% of the stones in the clay are thrown out by the threaded roll. The smaller stones are crushed to size from dust to that of a large pea. The clays are passed from the conical rolls to a large storage and mixing pile. Here all the different strata of clay are thoroughly mixed. The mixing of these various clays in this manner gives a uniform product and also distributes the stone throughout the material. From the storage pile the clay is reclaimed by an underground conveyor and passed onto a clay cleaner.

The clay cleaner consists of two parts, a large pug mill and a set of smooth rolls. The clay enters the cleaner at one end where it is mixed with the proper amount of water. As the clay is worked on down to the other end it is thoroughly pugged. A large wiper at the discharge end of the machine pushes the pugged clay through a small opening into the crux of the rolls. These rolls are superimposed and both run at a speed of about 260 r.p.m. The rolls, being only 18 inches in diameter have a large angle of nip, hence the wet and smooth stones with a coating of clay on them are not readily gripped by these surfaces. Consequently, the stones which are about $\frac{1}{2}$ inch in size ride on the crux, being passed out to the end by an oscillating finger and discharged. Stones too small to be retained are readily crushed to a very fine mesh. These rolls are kept a little less than $\frac{1}{16}$ inch apart. To use these rolls successfully, they must be kept very smooth and uniform. To do this they are reground after every million brick.

Clay passing through the clay cleaner is then ready to go on to the brick machine pug-mill where all these bits of stone dust are intimately mixed throughout the clay.

The result of this combination of processes has been a salvation for the brick plant on which it is being used. Today, out of a clay that at one time was utterly useless on account of the vast quantity of stone in it, we can produce a very high grade sandmolded brick. This system has been in operation in its entirety for six months and so far we have had no indication of limestone in our product.

Removal of Pyrites

Before going any further it should be mentioned that while we have concerned ourselves mostly with limestone there is also present in this clay a very large quantity of iron pyrites. The pyrites are in cubical form and range from $\frac{1}{16}$ to $\frac{1}{2}$ inch. Conical rolls will not do very much for them. If these pyrites pass on to the brick without being ground

very fine they will cause the brick to crack badly and render them valueless.

Cost of Operation

The labor required practically is the same no matter which system is used. One extra man is required to feed the belt in the storage system, assuming that the production does not exceed 8500 brick per hour. The usual hoist operator tends the feeder and the conical rolls and the regular man at the pug-mill runs the clay cleaner.

The power required to operate the feeder and conical rolls is about 60 to 75 horsepower, which is the same for a similar feeder and an ordinary disintegrator. The clay cleaner uses 75 to 100 horsepower, depending on conditions which vary a great deal. This is about 50% more power than would be required to operate an ordinary closed end pug-mill and its feeding conveyor.

The investment charge on this equipment is somewhat higher than the ordinary equipment, but on an output of a million a month it is very small.

Benefits Derived

On the other side of the ledger against the added expense of power and overhead are (1) improved quality of ware and (2) reduced losses. The improved quality is especially important where you have competition. Better brick means more business and a stability of trade. How much this means in dollars and cents is for each individual to determine for himself.

The item of losses in manufacture is one that stays at home for constant observation and in this item is the dollar and cents benefit. It was nothing unusual for this plant to throw away from 50,000 to 75,000 bricks out of one kiln of 245,000 on account of the limestone and iron pyrites. This would not happen with every kiln, but at times when we would run unwittingly into a deposit of half-disintegrated limestone. The pyrites no one ever sees until the brick are fired. In every kiln we would haul to the dump from 5,000 to 10,000 brick broken by these stones, to say nothing of the rebates that had to be made to customers to whom we had unknowingly delivered some of these defective brick.

In two cases we had to tear down the walls of a partially built structure and rebuild them, paying for the brick and labor in doing so. Such expenses as these are absolutely eliminated since we have installed this process. Incidentally, we are selling more brick at a better price with a direct saving of about 50 cents per thousand in the cost of manufacture.

Recapitulation of Process

1. Careful digging of clay.
2. Careful feeding of the conical rolls.
3. Elimination of all stones larger than one inch as far as possible.
4. Grinding all stones through the conical rolls as small as possible.
5. Thorough mixing to prevent slugs of finely ground stone passing into the brick machine, subsequently getting a large amount in a single brick.
6. Regrinding through $\frac{1}{16}$ inch opening all material going into the brick.
7. Repugging finely ground clay and stone dust to get a uniform distribution.

LANCASTER BRICK COMPANY,
LANCASTER, PA

INSULATION OF CERAMIC KILNS[1]

By Walter Kennedy

Abstract

Description and results of insulation are given.

One of the many important problems with which the ceramic engineer of today has to contend is the steadily increasing cost of fuel and consequent higher production costs. Ceramic engineers have for a long time generally agreed that at least 25% of the heat developed in firing a kiln is lost by conduction through the brickwork and by radiation from exposed surfaces. A considerable amount is also absorbed in the large volume of brickwork used in the walls, bottoms and flues and in the earth upon which the kilns are built. Raymond M. Howe, in a paper read before the Kentucky and Southern Ohio Branch of the Refractory Manufacturers' Operatives' Institute in January, 1923, advanced the following heat distribution ranges for the ordinary down-draft kiln:

	Per cent
Lost in unburned ash	1.6– 3.9
Taken up by kiln and lost by radiation	33.3–59.7
Stack loss	27.3–57.1
Used in firing ware	8.0–19.5

As an indication of the vast amount of heat absorbed in the earth underneath kilns, one Missouri firebrick manufacturer who tore down a kiln and had occasion to excavate twelve feet below the ground level, found the earth there too hot to touch two weeks after the last kiln of ware had been drawn. Numerous similar instances have come to our attention.

Probably the first attempt at reducing radiation losses from kilns was the building of very thick walls. Walls from 4 to 6 feet thick have been constructed and while they do reduce the radiation loss during the firing, the great mass of brickwork which must be heated assimilates nearly as much heat as would be lost by conduction through a thinner wall. Furthermore, the thick walls are expensive in material and labor and occupy needed space. Even had this method been found satisfactory, it would obviously not be feasible on crowns, due to the excessive weight.

Another method tried was the so-called "dead-air space" built into kiln walls. This method has been used satisfactorily for refrigeration work but at the temperatures employed in firing brick this artifice defeats its own purpose because the hot surface of the air space radiates heat so rapidly that a greater amount is lost across the space by radia-

[1] Presented before meeting of Pittsburgh Section Oct. 20, 1924. Recd. Oct. 25, 1924.

tion than would be conducted were the space to be filled with material of relatively high conductivity, such as fire brick. The quantity of heat passing through a portion of a solid wall by conduction depends on the difference between the temperatures of the two planes limiting the portion of the wall, while the quantity of heat that passes by radiation across the air space in the wall depends on the fourth power of the absolute temperatures of the surfaces enclosing the air space. Therefore, in the case of the heat passed by conduction through a solid

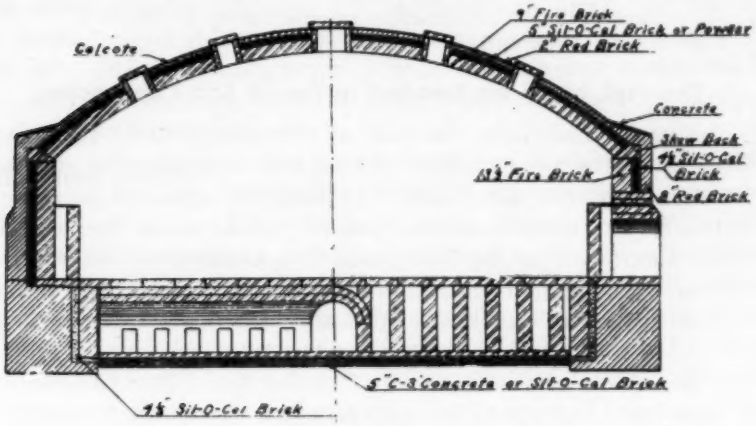


FIG. 1.—Method of insulating R.D.D. Kiln.

wall, the loss remains approximately the same as long as the relative temperatures of the two limiting planes remain constant, no matter what may be the actual temperatures of the two planes. On the other hand, the heat passing across the air space by radiation and convection increases rapidly with the temperatures of the enclosing surfaces, although the difference between these temperatures may remain constant.

This subject is gone into in considerable detail in the U. S. Bureau of Mines, *Bulletin*.[1] This principle explains why hollow tile, while very satisfactory in ordinary building construction, affords no insulating value if used in high temperature equipment. Another illustration of this principle is the thermos bottle, in which liquids can be kept cold for 72 hours and hot for only 24 hours.

Characteristics of Insulation

It is now generally accepted that the only satisfactory method of reducing heat losses through the walls of any high temperature equip-

[1] Kreisinger and Ray, "Flow of Heat through Furnace Walls," U. S. Bur. Mines, *Bull.*, **8** (1912).

ment is to install as a component of the wall a layer of material having a low conductivity and a low specific heat. Briefly, the ideal insulation for kilns or other equipment where analogous conditions prevail, should have the following properties:

1. High heat insulating value.
2. Sufficient refractoriness so as not to change form or lose its efficiency when subjected to high temperatures.
3. Sufficient mechanical strength to resist wall strains due to expansion and contraction of the brickwork with changing temperatures.
4. Approximately the same coefficient of expansion as the brickwork.
5. Light weight (desirable for crown insulation).

Thorough Insulation Standard in Tunnel Kiln Construction

Continuous tunnel kilns, because of the great area of the exposed surfaces, would be very wasteful of heat due to conduction and radiation unless insulation were used. In fact, the absolute necessity of insulation for this equipment is so obvious that the writer does not know of any attempt ever having been made to operate tunnel kilns without insulation. From 9 to 12 inches of insulating powder is used over the crown and from 4 to 6 inches of insulating brick or powder in the side walls.

The tunnel kiln of the Bradford (Pa.) Brick and Tile Company has been described.[1] At a point in the kiln where the internal temperature just beneath the crown is 1980°F, the temperature through the 9-inch firebrick arch is 1450°F. The temperature on the outside of the 9 inches of insulating powder is 150°F. This is an excellent practical demonstration of the effect of insulation.

Methods of Insulating Periodic Kilns

This paper will be confined particularly to periodic kilns. The larger portion of the heat loss through insulated kilns is naturally sustained through the crowns due to the relatively thin construction which must be used to obviate having too much weight on the crown itself. Insulating brick weigh only $1\frac{3}{4}$ pounds each and this is so slight as to be practically negligible as far as its effect on the crown is concerned.

Side walls of periodic kilns are usually insulated with $4\frac{1}{2}$ inches of insulating brick. Insulating powder is sometimes used for this purpose also. In a wall 27 inches thick, $13\frac{1}{2}$ inches of refractory is used in front of the insulation and 9 inches of brick on the outside of the insulation. The walls can be bonded through the insulation by the use of either 9-or $13\frac{1}{2}$-inch firebrick headers. Another method which has been perfectly satisfactory is the use of metal wall ties, consisting of crimped

[1] *Brick and Clay Rec.*, Dec. 27, 1921.

metal strips 12 inches long extending through the insulation course and approximately 4 inches into the other brick on either side.

The usual method of insulating bases is to use either one or two 2½-inch layers of insulating brick or five inches of insulating concrete (the latter being composed of calcined insulating material and Portland cement).

Advantages of Kiln Insulation

The most tangible advantage of insulation in kilns, and the one most readily convertible into dollars and cents savings, is the reduction in fuel bills. Other advantages which result are, however, considered by many users of insulation to be of more importance in the aggregate than the direct saving in fuel.

(a) Improved Quality of Firing It is a logical result of insulation, due to the blanketing effect of the insulating material, that the heat which cannot escape through bottoms, walls, and crowns, will naturally tend to distribute itself more uniformly through all parts of the kiln. In uninsulated kilns it is often necessary to force the fires and overfire near the fire-pockets and at the tops in order to bring more remote sections of the kiln (at the center of the load and at the bottom) up to the required finishing temperature. One refractory plant in the Pittsburgh district reduced the percentage of soft brick from 1.2% to 0.25% after insulating crowns and bottoms with Sil-O-Cel brick. Cones 6 and 7 were put down in the bottom of this kiln instead of cone 4 before insulating and this was accomplished without increasing the temperature at the fire-pockets. Insulated kilns are not susceptible to atmospheric conditions, which is especially important in climates where wide variations in temperature are encountered.

(b) Reduction in Firing Time Considerable reductions in firing time are effected by thorough insulation of kilns, which reduces the labor cost of firing and increases the kiln turn-over. At one plant where the bottoms and crowns were insulated the firing time was reduced from an average of 163 hours before insulating, to an average of 135 hours after insulating. This reduction of over one day amounts to a considerable item in a year's time. For instance, using the above figures as a typical example, the reduced time necessary for firing would enable ten insulated kilns to be fired off and to produce the same amount of ware as previously turned out of twelve uninsulated kilns. The result is that with the same kiln equipment, insulation will increase production considerably without additional expense for building kilns. This additional kiln capacity is always expensive to obtain by any other method.

(c) Longer Life of Crowns, Walls and Fire Pockets

In one or two isolated cases insulated crowns have given trouble but in these instances it was found to be due to faulty construction rather than to any fundamental factors governing the feasibility of insulating. The crown being exposed to maximum temperatures should naturally always be carefully built of a good quality refractory, the failing point of which under a load is reached at a considerably higher temperature than is required or will be reached in firing the kiln of ware. Where a good refractory is used there is no danger in insulating. Crowns which have been insulated for from six to eight years are still in excellent condition. In fact, it is now quite generally conceded that the effect of insulation is to increase the life of the crown brick due to the fact that the insulation results in a more uniform temperature throughout the 9-inch crown, with a natural reduction in internal stresses and strains and resultant cracking. Similarly, in the side walls of kilns, insulation prevents excessive temperatures from penetrating to the outer wall of common brick.

The necessity of forcing fires is obviated to a great extent by the use of insulation and the life of the fire-pockets is considerably lengthened.

Savings in Fuel

In practically every case where insulation has been used in kilns, careful records have been kept of fuel consumption and comparison made with records on the same kilns before insulating or with records on uninsulated kilns of the same size. While in some cases the savings have been found to be as high as 20% for thoroughly insulated kilns, it is generally conceded that from 16 to 17% is a very conservative figure. Most of the saving is undoubtedly effected by the crown insulation. Due to the fact that thinner side walls can be built, the cost of includ-

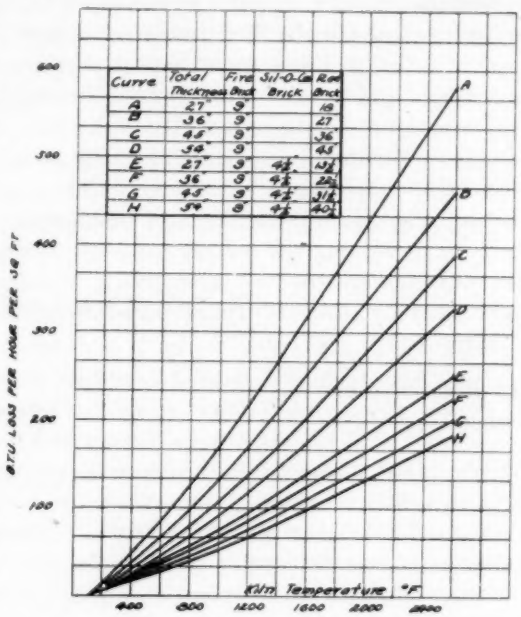


FIG. 2.—Comparative heat losses through insulated and uninsulated kiln walls.

ing insulation in side walls is little if any more than if insulation were not used. Base insulation, in addition to effecting considerable fuel saving, is an important factor in increasing bottom temperature and improving the quality of firing. Figure 2 shows the comparative B.t.u. loss through insulated and uninsulated kiln walls of various thicknesses. Similarly, Fig. 3 shows the comparative losses through various crown constructions.

Kilns for firing practically all kinds of ceramic products have been successfully insulated, including fire brick, common brick, paving brick, sewer pipe, pottery, and various kinds of tile, terra cotta and porcelain.

In some cases, of course, it is difficult to measure definitely the fuel savings which are being secured by insulation, due to a haphazard system of coal distribution or for some other reason. The fact that the insulation is saving fuel is very apparent, however, in every case. A comparison of exterior temperatures of insulated and uninsulated crowns will give a good indication of what is being accomplished. In Fig. 4 is shown the comparison in temperatures of insulated and uninsulated crowns, these curves being plotted from actual readings taken by the ceramic engineer of a representative plant.[1] Exterior crown temperatures of kilns built in the open are affected greatly by atmospheric conditions. Wind velocity is a particularly important factor. On a comparatively calm day the temperature of a crown may be 250°, while on a windy day, other conditions being the same, the temperature may be only 200°. More heat will be lost on the windy day, however,

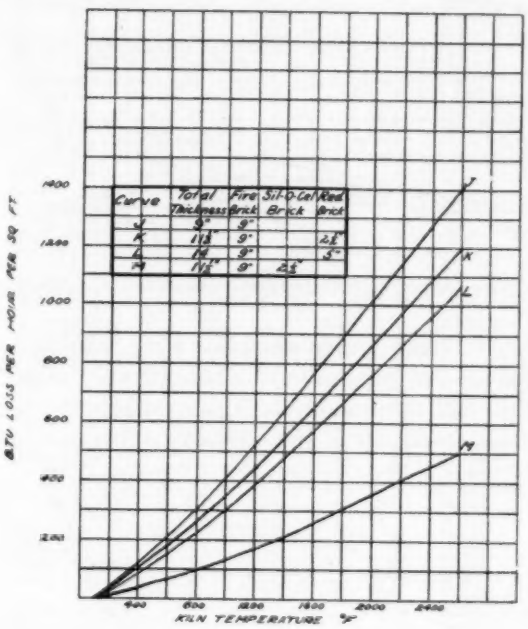


FIG. 3.—Comparative heat losses through insulated and uninsulated kiln crowns.

[1] J. H. Kruson, A. P. Green Fire Brick Co., Mexico, Mo.

than on the calm day, as in the former case the heat is carried away more rapidly.

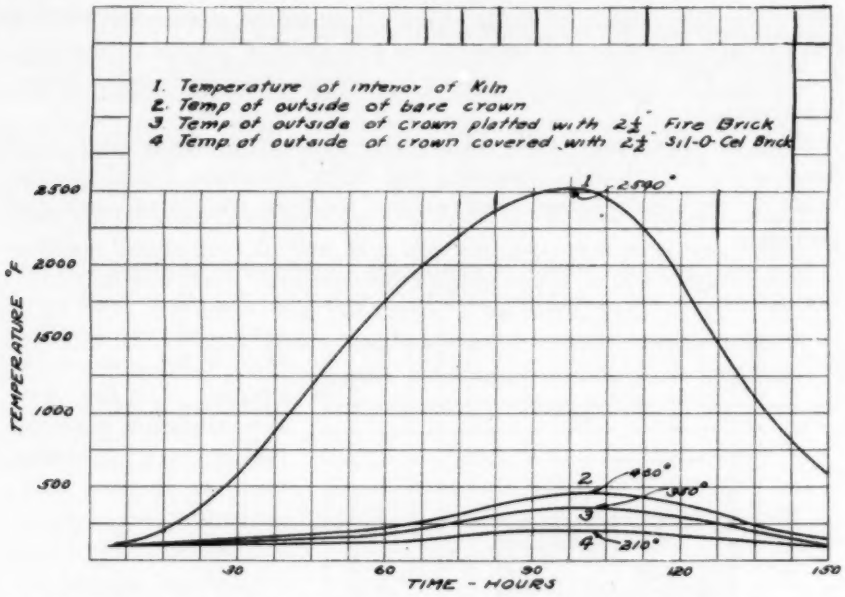


FIG. 4.—Comparison in exterior, temperatures on insulated and uninsulated kiln crowns.

Furthermore, in a number of cases where old kilns were insulated, it was found necessary to reduce the grate area to eliminate the danger of over-firing. The improved quality of ware and the reduction in the firing time are always conclusive evidence of the economy of insulating.

CELITE PRODUCTS COMPANY,
CHICAGO, ILLINOIS.

ERRATA: H. H. Clark, *Jour. Amer. Ceram. Soc.*, **8** [10] 623-25 (1925). Page 624, line 36, decimal points were omitted and sentence should read: "The pieces were of sizes varying from $3\frac{1}{2}$ square feet to .3 square foot; 8 pieces to 100 pieces per load".

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

ROSS C. PURDY, Editor
EMILY C. VAN SCHOICK, Asst. Editor

ABSTRACTORS: OLAF ANDERSEN, A. A. AYARS, C. E. BALES, W. M. CLARK, S. S. COLE, R. R. DANIELSON, H. G. FISK, F. C. FLINT, R. E. GOULD C. J. HUDSON, F. G. JACKSON, W. R. KERR, R. M. KING, S. KONDO, A. H. KUECHLER, R. D. LEITCH, J. T. LITTLETON, JR., M. E. MANSON, T. N. MCVAY, R. J. MONTGOMERY, LOUIS NAVIAS, O. P. R. OGILVIE, E. E. PRESSLER, W. E. RICE, W. SCHMIDT, H. G. SCHURECHT, D. E. SHARP, H. F. STALEY, H. H. STEPHENSON, E. J. TE PAS, A. E. R. WESTMAN, F. A. WHITAKER.

Vol. 5 February, 1926 No. 2

Author Index[1] to Ceramic Abstracts for February

Arthur, E. P. 48
Atkinson, J. S. 47

Bailey, K. C. 43
Bancroft, W. D., and Jenks, L. E. 65
Barnett, P. W., and Bakewell, B. 44
Barringer, E. C. 46
Bauer, P. 46
Bertolini, D. 70
Bingham, E. C. 65
Bingham, E. C. Rolland, G. F., and Hilbert, G. E. 72
Blair, J. C. 53
Bloom, F. S. 62
Booer, J. R. 66
Booze, M. C. 70
Bowen, N. L., and Greig, J. W. 69
Bragg, W. H. 65
Brasseur, G., and Andris, A. 54
Brown, R. P. 62
Buckley, L. C. 61
Burley, W. L. 63

Campbell, T. B., Jr. 53
Cantrell, M. 59
Collins, N. L. 69
Cox, P. E. 73
Curtis, A. L. 57
Curtis, E. deF. 70
Curtis, T. S. 55

Desch, C. H. 68
Duclaux, J., and Errera, J. 67
Dunlap, O. W. 61
Durand, V., Jr. 54

Eckert, F. 48
Elam, C. F. 46
Emery, W. 58
Evans, J. W. 68

Farnsworth, M. 45
Fitzgerald, F. A. J. 62
Forsythe, W. E. 61
Fox, C. S. 58
Fowle, A. E. 52
Frerichs, H. G. 59

Gallagher, B. J. 62
Gelstharp, F. 52
George, W. O. 68
Gilard, P. 58
Gonnerman, H. F. 44

Hadfield, R. 45
Hallimond, A. F. 67
Hanoy, G. B. 55, 56
Harman, R. W. 66
Harrington, A. L. 51
Harty, Wm. A. 59
Hayden, B. F. 55
Helberger, H. 50
Henderson, J. C. 53
Henderson, T. 56
Hill, C. W. 70
Hitchcock, H. K. 51
Hotelling, H. 72
Hughes, G. F. 57
Hunt, M. H. 60
Hursh, R. K. 61
Hybinette, N. V. 46

Ivanovsky, N. I. 73

Jones, H. C. 49

Keeney, R. M. 71
Keppeler, G. 67
Keyssiner, E. 44
Kinzie, C. J. 69
Klopstock, H., and Neumann, W. 69
Kohl, H. 60

LeChatelier, H. 50
LeCoultre, F. C. F. 59
Lodge, O. 69
Lu, K. C. 64

McAfee, W. K. 70
McDowell, J. S. 64
McKee, R. H. 70
Marckwald, W., and Gebhardt, H. 66
Martin, J. D. 73
Mason, W. 57
Mauri, A. 49, 50
Mayer, H. 69
Miller, J. E. 61
Mitchell, W. C. 54
Moorshead, T. C. 49
Morey, G. W., and Bowen, N. L. 63
Moser, E. 62

Niggli, P. 68
Noack, E. H. 46

Oakley, W. W. 47
O'Shaughnessy, T. A. 50
Owen, W. 52

Parks, W. A. 71
Pence, F. K. 71
Pfeil, C. W. 46, 47
Piwowarsky, E. 45
Porter, R. 68
Potts, A. P. 70
Prentice and Christman 46

[1] The abbreviation (*C.A.*) at the end of an abstract indicates that the abstract was secured from *Chemical Abstracts* by coöperative agreement.

Author Index to Ceramic Abstracts for February (*Continued*)

Quartz and Silica 60
Ranagan, W. H. 50
Rand, C. C. 60
Requa, R. S. 56
Richter, G. M. A. 42
Riddle, F. H. and Peck, A. B. 57
Roberts, S. G. 48
Ross, G. 71
Ross, R. F. 61
Roth, G. 73
Ryan, J. F. 56
Scofield, S. W., and LaRue, J. B. 59
Scott, V. H. 47
Seashore, C. E. 72
Seashore, C. E., and Metfessel, M. 43
Slater, A. V. 60
Slingluff, H. G. 53
Smith, G. O. 48
Smith, W. 49
Soc. d'Etude des Agglomeres 59
Soubier, L. D. 50
Spacu, G. 66
Specketer, H. 60
Springer, L. 49
Sproesser, W. C. 47
Stefer, W. 58
Steimer, T. C. 52
Stevens, H. P. 67
Stewart, I. 58
Stull, R. T. 63
Thompson, R. C. 43
Tool, A. Q., and Hill, E. E. 47
Treadwell, W. D., and Köbl, A. 67
Waksman, S. A. 66
Watts, A. S. 70
Weaver, M. T. 71
Weil, R. 67
Wyckoff, R. W. G., and Morey, G. W. 47
Young, G. H. 58
Youngman, R. 59
Zocher, H., and Reinicke, F. 43
Zschimmer, E. 45

Art

Three red-figured Greek vases. GISELA M. A. RICHTER. *Bull. Met. Mus. Art*, pp. 26–164, Nov. 1925.—The Museum has recently acquired three unusual red-figured Athenian vases. One is a magnificent krater with volute handles set on a separate stand, the total height of which is 26 inches. This vase is a beautiful compn. of subtly interrelated parts and is comparable to an architectural design. To appreciate this vase as well as the peculiar beauty of Greek shapes in general, one must take the same interest and pleasure that the Greeks did in symmetry and proportion. The decoration of the krater is adapted to give full value to the various parts. Each of the four moldings of the rim has a delicate pattern. The body is black but the moldings of the foot and stand have occasional red bands to emphasize their distinctness from one another. The center of interest is the figured decoration on the neck. The subject is Dionysos with satyrs and maenads dancing and playing. The delicate figure drawing is that of the second half of the fifth century. The names of the figures are in white letters. In subject and style these scenes can be connected with three Calyx Kraters in the British Museum; in the possession of Mr. Gulbenkian and formerly in the Hope collection; and in Vienna. The Hope, The British Museum and our own krater are very close in style and by the same artist, some of the figures repeating the identical poses almost line for line. The other two vases are both of the bell krater shape, of fine proportion, showing in their slight variations from each other the variety that can be attained in the same form by slightly changing the curve of the body, foot or rim. They are works of the Early Free Style (460-420 B.C.) and can be attributed to well known Athenian vase painters. The larger of the two vases is by the Villa Giulia painter so named after one of his chief works, the Women Holding Hands in the Villa Giulia Museum. It is decorated with tall standing figures, Apollo, Artemis and Leto, on one side and on the other an old man with white hair and beard, and two women. There is a good deal of repetition in the painter's work as he was not so much interested in inventing new motives as he was in producing his quiet, majestic pictures. The second bell krater has been attributed by Beazley to the Danaë painter, the artist of the hydria in Boston with Danaë and Perseus in the chest. On its main side there is a woman seated on a cushioned chair playing the lyre while two companions stand in rapt attention. The poses are unusual and the women have a dreamy far away expression, being much moved by the music. This representation of emotional exaltation is rare and is comparable to the Orpheus painting in Berlin and the three musicians on the Amphora in the British Museum. At the back of the vase are three standing women in Ionic chitons and mantles with fillets in their

hair. These paintings are similar to another attractive musical scene by the Danaë painter on a bell krater in Vienna with Apollo, and two Muses, one playing the flute, the other the lyre. A. A. A.

Deviation from the regular as an art principle. C. E. SEASHORE and M. METFESSEL. *Proc. Nat. Acad. Sci.*, **11**, 538–42 (1925). H. H. S.

The pigments of the ancient Romans as described in the natural history of the elder Pliny. K. C. BAILEY. *Jour. Soc. Chem. Ind.*, **44**, 1135–37 (1925).—Gives the chem. compn. of Roman pigments, and shows that some names such as Uva, "the grape," which editors of Pliny had rejected as unintelligible when applied to the green chrysocolla, is due to the fact that it was composed of malachite, $CuCO_3\ Cu(OH)_2$, which is often found in botryoidal form. H. H. S.

On the origin of the impression of luster. H. ZOCHER and F. REINICKE. *Zeits. f. Physik*, **33** [1–2], 12–27 (1925).—After a brief mention of the literature on the subject, ref. being made to the early work of Wundt and of the recent work of Esslen (*Naturwiss.* **10**, 1056 (1922)) and of Bancroft (Abstract 1031 (1919)), the author discusses in general terms the cause of luster or gloss and methods of producing the impression of luster which may be obtained by the employment of suitably arranged surfaces. These surfaces may consist of mats. having a matt surface. From a phys. point of view, luster is defined as incomplete regular reflection. From a consideration of the nature of the surface a distinction is drawn between reflection luster and matt luster. The luster of diamond, glass, or water comes in the first class, and mother-of-pearl and fat in the second. Surfaces which show reflection luster when considered on a very small scale (like the human skin) may show a matt reflection on a large scale. The consideration of the different circumstances (variation of color and light and shade) which lead to the impression of luster are next discussed. Metallic reflection is due to intensity of luster while a substance like barium sulphate may diffusively reflect nearly all the light which falls on it without the impression of luster. The perception of solidity is next discussed, and the effect of stereoscopic vision. The remainder of the paper gives numerous examples of methods of producing the illusion of luster. Many of these methods are employed in the textile industry; *e. g.*, Schiller or changeant fabric and the Moirée effect may be cited. T. B.

BOOK

The chemistry of the ancient Assyrians. R. C. THOMPSON. London: Luzac and Co., 1925.—It is shown among other things that the Assyrians knew how to make aventurine. H. H. S.

Cement

Casein and its industrial applications. ANON. Memorandum Natural Resources Intelligence Service, Ottawa, Canada. *Jour. Soc. Chem. Ind.*, **44**, 986–95, 1009–11 (1925).—The manuf. of casein and its applications in the arts are described. The chief producing countries are the U. S., Argentina, and Canada. It is used in the paper industry, in adhesives and cements, in plastics (erinoid, galalith, ingalite, lactoform, cornalith, lactite, lactoite, aladdinite, karolith, sicalite and protealite), in paints, medicinal preparations and foods, in printing calico and textiles, in soap, asbestos products, fungicides, etc. Silicate-lime-casein cements for porcelain, metals, glassware, plywood and veneer products, have somewhat of the formula: Mix 100 parts casein with 130-280 parts water and stand 15 mins.; mix separately 15-22 parts hydrated lime with 90 parts water; mix the above two compns. together with 70 parts silicate of soda. Casein-alkali glues are also available, the alkali commonly used being borax. H. H. S.

Iodine in cement kiln flue-dust. E. KEYSSINER. *Chem. Ztg.*, **49,** 221 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 883 (1925).—Iodine as KI may be detected in flue-dust by extraction with water and slaking with CCl_4, concd. HCl, and $NaNO_2$ soln. Colorimetric detns. indicated 50 mg. KI per kg. This may come from the limestone or from the coal, in both of which iodine may be frequently detected. H. H. S.

Jointless magnesium oxychloride floors. P. W. BARNETT and B. BAKEWELL. Building Research Board, London. *Bull.* **1**, *Jour. Soc. Chem. Ind.*, **44,** 1019 (1925).—Part 1 of the bulletin summarizes existing information on Mg oxychloride cements, describes the mats. used, the method of mixing and laying, and the advantages and disadvantages of jointless floors, and discusses the specif. for caustic magnesia. Part II gives an account of the research done in order to eliminate the corrosive action of these cements on iron work. The object is stated to be attained by the substitution of $FeCl_2$ for $MgCl_2$. The properties of the new cement are discussed in detail. H. H. S.

Effect of size and shape of test specimen on compressive strength of concrete. HARRISON F. GONNERMAN. Structural Materials Research Laboratory, *Bull.* **16,** Dec. 3, 1925. Tests were made on 1755 concrete specimens at ages of 7 days to 1 year in a study of the compressive strength of: (1) Cylinders 1½ to 10 in. in diameter, 2 diameters long; (2) Cylinders 12 in. long, 3 to 10 in. in diameter; (3) Cylinders 6 in. in diameter, 3 to 24 in. long; (4) Cubes, 6 and 8 in.; (5) Prisms, 6 by 12 and 8 by 16 in. The relative strength of the different forms of specimen was compared with the strength of 6 by 12 in. cylinders from the same concrete. The principal conclusions are: (1) The 6 by 12-in. cylinder generally used for compression tests of concrete, as recommended by the American Society for Testing Materials, is a satisfactory form of specimen. However, this size of cylinder should be limited to aggregates not larger than 2 in. in diameter. Four by 8-in. or 5 by 10-in. cylinders are suitable for the smaller sizes of aggregate. The ratio of diameter of cylinder to maximum size of aggregate should not be less than about 3. For aggregates larger than 2 in., 8 by 16-in. cylinders or larger should be used. (2) For cylinders of length equal to 2 diameters, lower strengths were generally obtained with the larger cylinders. The decrease in strength with size of cylinder was not important for diameters of 6 in. or less; 8 by 16-in. and 10 by 20-in. cylinders gave 96 and 92% of the strength of 6 by 12-in. cylinders. (3) Concrete cylinders having a ratio of length to diameter of from 0.5 to 4.0 gave the following average strength-ratios at 28 days:

Ratio of length to diameter	0.5	1.0	1.25	1.5	2.0	3.0	4.0
Strength-ratio, percentage of strength of 6 by 12-in. cylinder	178	115	107	103	100	95	90

These strength-ratios agree with those reported by other investigators. The difference in strengths of cylinders having ratios of length to diameter between 1.5 and 2.5 was not important. (4) The 6 and 8-in. cubes tested at ages of 7 days to 1 year gave strengths averaging 18 and 13% higher than 6 by 12-in. cylinders. The strengths for 6 by 12 and 8 by 16-in. prisms were lower at all ages than that for 6 by 12-in. cylinders; the strength-ratios averaged 93 and 91%, respectively. (5) For all forms of specimens the compressive strength increased with age for moist curing. For cylinders and prisms of length equal to twice the diameter or width, the 7-day, 3-mo. and 1-yr. strengths averaged 52, 142 and 178% of the 28-day strength for 1:5 concrete. The corresponding percentages for 6 and 8-in. cubes were 60, 129 and 165%. (Reprinted from Proc. A.S.T.M., 1925).

Early high temperature in alumina cement concrete. ANON. *Eng. News-Record* **94,** 320 (1925).—In cold weather freshly poured concrete must be kept above the temp. at which setting is retarded. This point, for Port. cement, is approx. 50°F. Meas. supporting the contention that higher temps. are developed in setting of alumina cement than in Port. cement and that the former is therefore more suitable for use in low temps.

are given. Tests showed that heat generated in alumina cement was sufficient to prevent freezing until concrete had hardened and developed considerable strength. (*C. A.*)

BOOK

Water softening. ANON. *Natl. Lime Assn. Bulletin.* This *Bulletin*, which is 6 in. by 9 in. in size, contains 48 pages of extremely interesting and valuable information, easily read and well illustrated. The treatment of the subject is non-technical as far as possible and the *Bulletin* will be of interest and value to all those who have anything to do with water treatment. There are four main chapters in this new publication, each relating to a particular phase of water softening or treatment. These chapters have been prepared by authorities and carry a valuable message. The first, "Advantages of the Use of Lime in Water Treatment," is by C. P. Hoover of Columbus, Ohio. The second discusses "The Cost of Impurities in Locomotive Water Supply and Value of Water Treatment" and is from the report of the Water Service Committee of the American Railway Engineering Association. The third chapter, "Raw Water Ice," presents much valuable information in unusually interesting style. C. Arthur Brown prepared the last chapter, "Some Variants from Accepted Formulas in Water Flows," and has clearly explained and simplified a number of the mathematical formulas commonly used by water works superintendents and operators. This *Bulletin* will be sent free upon request to the National Lime Association, 918 G Street, N. W., Washington, D. C., or 844 Rush Street, Chicago, Illinois, or any member company. R. P. B.

PATENT

Method for manufacturing gypsum from anhydrite. MARIE FARNSWORTH. U. S. 1,566,186, Dec. 15, 1925. A method for forming gypsum from anhydrite which comprises grinding anhydrite to a size between the limits in which the largest particles do not exceed substantially 135 microns with an average size of 18 microns to that in which the largest particles do not exceed substantially 30 microns with an average size of substantially 7 microns and hydrating the ground anhydrite.

Enamel

Glasses, glazes and enamels. ED. ZSCHIMMER. *Ceram. Ind.*, **5** [6], 518–19 (1925).—Z. gives tables showing the formulas of ground coats and cover coats, for sheet iron. The enamels are compared to resist. glasses. Limits of the constituents for glasses, enamels and glazes for various purposes are given, with the reasons for the limits. P. D. H.

Three rotary electric furnaces enamel 11,780 square feet. Triple coat daily. ANON. *Ceram. Ind.*, **5** [6], 526–31 (1925).—The plant of the Detroit Vapor Stove Company, Detroit, Mich. is described. Ware is pickled on a continuous conveyor, dried in a continuous drier and enameled in rotary elec. enamel furs. The plant has many novel features. P. D. H.

French metallurgy. R. HADFIELD. *Jour. Soc. Chem. Ind.*, **44**, 1029–44 (1925). H. H. S.

Manganese steel: Curious and unexplained facts. R. HADFIELD. *Jour. Soc. Chem. Ind.*, **44**, 1042–44 (1925). H. H. S.

Influence of temperature on graphite formation in iron. E. PIWOWARSKY. *Stahl. u. Eisen*, **45**, 1455–61 (1925); *Jour. Soc. Chem. Ind.*, **44B**, 805 (1925).—The heat of formation of iron carbide is first negative (1150–1500°), passes through zero (1500–1550°) and then becomes positive (1550–1560°). On iron becoming molten, both iron carbide and elementary C go into soln., but the C tends to change into the carbide mol. arrange-

ment, two kinds of mols. in fluid iron being inferred, the carbide and C arrangements respectively. To test the sluggishness of the mol. transformation, iron with 2.4% Si was heated to 1600°, cooled to 1400°, and maintained at that temp. for different periods. The combined C was found to increase with time, but at 1200° hardly any effect was observed. H. H. S.

Orientation of crystals produced by heating strained iron. C. F. ELAM. *Iron and Steel Inst.*, Sept. 1925; *Jour. Soc. Chem. Ind.*, **44B,** 806 (1925).—Square etching pits with a diagonal in the direction of straining, are frequently obtained in large crystals produced by annealing strained iron. The crystal axes, relative to the direction of straining, of ten crystals were detd. by X-ray anal. and the orientation was shown to be varied. Only two crystals showed cubic etching pits, and in both of these the surface of the strip was parallel to a cubic (100) plane in the crystal. Crystals of other orientation only showed pitting after prolonged etching; it should therefore be possible to pick out these crystals in which a (100) plane lies in or near the plane of section. H. H. S.

Cleans castings hydraulically. E. C. BARRINGER. *Foundry*, **53,** 951–54 1925.—The Allis Chalmers Co. now clean their castings with water under 425 lbs. press. The press. is developed with a 4 in., 6 stage, centrifugal pump driven by a 300 h.p. motor, delivering 800 gal. of water per min. at a 900 ft. head. The castings are placed in a concrete room, in whose walls the nozzles are fastened. The operator stands outside the room and watches the work through reinforced glass windows. The water is cleaned and recirculated. As an example of the saving obtained, a casting which formerly required 300 hrs. to clean is now cleaned in 14 hrs. Two men are doing the work that used to require 60. M. E. M.

The practical enamel smelter lining. PRENTICE and CHRISTMAN. *Fuels and Fur.*, **3** [11], 1280 (1925).—A lining of standard shapes is suggested to take the place of flux blocks now in general use. In using the 9 in. standard shapes, however, care should be taken that the refrac. mat. is such that it will resist the action of the enamel and that they be as true to shape as possible so as to minimize the effect of many joints. All precautions should be taken to secure a thin joint. By using the standard shapes and brick the enamel man can rest assured that he can secure a lining at a moment's notice: R. M. K.

Action of zinc oxide on unfritted lead-free enamels for sanitary enameled ware. P. BAUER. *Ber. deut. keram. Ges.*, **3,** 286–90 (1922); *Chimie et industrie*, **12,** 1067 (1924).—After studying several enamels of the type: 0.3 K_2O, 0.7 MO, 0.4–0.5 Al_2O_3, 4SiO_2, in which MO was replaced by ZnO and CaO, B. considers the following as the most interesting: 0.7 ZnO, 0.3 K_2O, 0.5 Al_2O_3, 4SiO_2. (*C. A.*)

PATENTS

Heat-resisting steel. EDWARD HENRY NOACK. U. S. 1,562,782, Nov. 24, 1925. A steel containing silicon between 1.50% and approximately 2.00%; copper between 0.50% and approximately 1.00%; manganese not over 0.12%; and carbon not over 0.10%.

Heat-resisting alloy and structure, etc. NOAK VICTOR HYBINETTE. U. S. 1,563,573, Dec. 1, 1925. Heat resisting alloys containing from 10 to 20% of chromium, 30 to 40% of nickel, from 0.4 to 1.5% carbon, less than 1% silicon and the remainder for the most part iron.

Process by which aluminum metal and its alloys may be applied to ferrous metal. CARL W. PFEIL. U. S. 1,565,495, Dec. 15, 1925. The process of applying an aluminum coating to a base metal which consists in very finely dividing the aluminum in a bath

of an air-excluding film-producing material, applying the compound thus formed to the metal to be coated, and heating.

Process for making and combining corrode-resisting metals. CARL W. PFEIL. U. S. 1,565,496, Dec. 15, 1925. A process of providing a corrode-resisting metallic combination for composite ferrous metals, which consists in heating a tin-coated ferrous metal until the tin melts and mixing finely divided aluminum with the molten tin until it can absorb no more.

Control of the softening temperature of vitreous material. WILLIAM CHARLES SPROESSER. U. S. 1,565,598, Dec. 15, 1925. The method of potentially increasing the softening temp. of vitreous material a desired amount comprising applying a mat. to the surface thereof to react chemically therewith.

Glass

Some factors involved in the preheating of glass pots with special reference to moisture control. W. W. OAKLEY. *Jour. Amer. Ceram. Soc.*, **9** [1], 23 (1926).—The moisture content of the atmosphere of a pot arch preheating covered pots is a very important factor. Heating in a humid atmosphere tends to equalize the rate of removal of moisture from the inside and the outside surface of the pot at temps. above 212°, decreasing mech. strains set up in this process.

Developments in furnaces for the glass industry. J. S. ATKINSON. *Fuels and Fur.*, **3** [11], 1271–75 (1925).—Descriptions are given of new developments in pot furs., tank furs. and annealing leers. Cuts and drawings are shown illustrating the design and operation of these furs. R. M. K.

On the density and constitution of glass. A. Q. TOOL and E. E. HILL. *Jour. Soc. Glass Tech.*, **9** [35], 185–207 (1925).—The fund. hypothesis on which this paper is based is that under proper cooling conditions certain processes or reactions practically reversible without drastic treatment and involving some or all of the constituent mols. of a glass shall advance in such a way that other possible and disturbing processes often associated with cooling and with treatments at temps. above the annealing range are prevented. Conclusions indicate that the condition of glass is one which is intermediate between the liquid and the solid state. Glass is undercooled both with respect to crystallization and to certain phys. and chem. processes which are normal to the vitreous condition. It has been shown that some of these at least advance or retrogress as the heat treatment is changed and that as a consequence certain properties are modified by altering the effective treating temp. The temp. is detd. by the period and temp. of treatment and by the mode of cooling. The changes in certain thermal effects and in the density and refractive index are within limits, practically reversible but these changes are small. R. M. K.

The viscosity of glass. VAUGHN H. SCOTT. *Jour. Soc. Glass Tech.*, **9** [35], 207–25 (1925).—This paper consists mainly of a comparison of the results of Washburn and Shelton in their work on the viscosities of various glasses with some data obtained in the National Physical Laboratory. The critical study by Le Chatelier of Washburn's and Shelton's results is also taken into consideration in this comparison. It is pointed out that the viscosity of glass is very sensitive to changes in constitution. R. M. K.

X-ray diffraction measurements on some soda-lime-silica glasses. RALPH W. G. WYCKOFF and GEO. W. MOREY. *Jour. Soc. Glass Tech.*, **9** [35], 265–67 (1925).—Some expts. were undertaken as a preliminary survey of an extensive system of glasses studied by Morey and Bowen, (*Ibid*, 226–64). Their purpose was to study the nature of glasses themselves and the mechanism of the quant. explanation of their X-ray patterns. In early study of X-ray diffraction effects it became known that glasses give rise to very

broad powder bands. It was found that diffraction patterns of these glasses do not conform in all cases to previous experience. It was found however that a close relation exists between the diffraction patterns of these glasses and certain aspects of the melting point diagram. Explanations of the various phenomena observed have been deferred until there is an opportunity to examine a larger number of glasses. R. M. K.

Some remarks on the constitution of glass. F. ECKERT. *Jour. Soc. Glass Tech.*, **9** [35], 267–72 (1925).—The problem of the constitution of glass has often been obscured because the question of the state of aggregation has been confused with that of constitution. The author discusses for the most part the dependence of glass upon its heat treatment for the explanation of its properties. R. M. K.

Optical glass production by Bureau of Standards. ANON. *Glass Worker*, **45** [2], 14 (1925).—An abstract from the annual report of the Director. Thirty pots of optical glass, approximating 40,000 lbs. were made but no consistent conclusions were obtained. However, some good glass was almost always obtained. This was used for exptl. work in molding and annealing. F. G. J.

Conveying raw materials and finished ware in glass plants. ANON. *Glass Worker*, **45** [2], 15 (1925). A description of the Link-Belt Co. conveyors. F. G. J.

An interesting glass tank port construction. E. P. ARTHUR. *Glass Worker*, **45** [2], 15 (1925).—Describes a construction once used to secure a better mixt. of air and gas. It consists of a refrac. box projecting into the interior of the port. There is a regular gas pipe burner in the middle. No data is at hand on performance. It is quite likely that maintenance and repair would be expensive. F. G. J.

Will try out new type of furnace in England. ANON. *Glass Worker*, **45** [9], 15 (1925).—T. C. MOORSHEAD, president of the United Glass Bottle Manufacturers, Ltd., announced that the U.G.B.M. would finance expts. on the principles proposed by ALEX FERGUSON for making hollow glass. The process includes an automatic gas producer of special design, means of preheating the sand and limestone used in the batch, a vertical conical fur. using tangential burners, means of using the waste heat for air recuperation as well as preheating sand and limestone, an automatic bottle mach. rotating on a horizontal axis and using the suction principle for feeding (the mach. resembles a miniature Ferris wheel), a specially designed leer which is substantially a retort. The coal is retorted here to soft coke and delivered to the producer at about 400°C. It is claimed that 6 tons of glass can be produced with 1 ton of coal. Full details are given. F. G. J.

Making Pyrex glass at Corning Glass Works. S. G. ROBERTS. *Glass Worker*, **45** [10], 15 (1925).—Reprinted from *Compressed Air Magazine*, Nov. 1925. An illustrated descriptive article. F. G. J.

Many improvements made at Cunningham glass plant make it full automatic. ANON. *Nat. Glass Budget*, **41** [33], 8 (1925).—A history of the D. O. Cunningham Glass Co., one of the old Pittsburgh companies, and an account of their modern equipment. F. G. J.

The use of lime in glass. G. O. SMITH. *Glass Industry*, **6** [12], 271 (1925).—Lime is used in making almost all kinds of glass. It imparts smoothness and brilliancy and increases resist. to chem. agents. Increasing the lime increases the fusibility to a certain extent and tends to prevent cords but also increases the tendency to devitrify. Glass with high lime is hard and brittle and must be annealed more carefully. There is a difference of opinion as to whether limestone or burnt lime should be used. The merits of both are discussed. Also the question of how much lime to use is open. The requirements of different types of machs. will determine this. F. G. J.

Glass chipping. WALTER SMITH. *Glass Industry*, **6** [12], 277 (1925).—An ornamental translucent non-transparent glass can be made by chipping. The surface is first sandblasted and then coated with glue. It is then dried and gradually heated in a gas-fired oven. The glue adheres and shrinks as it dries, finally flaking off and taking a chip of glass with each flake. By repeating the sandblasting and chipping a still more beautiful finish is obtained. F. G. J.

Modern street lighting glassware. ANON. *Glass Industry*, **6** [12], 278 (1925).—A description of the requirements and the process of manufacture of globes and canopies. F. G. J.

Changes give a tank 75% more glass output on less coal. ANON. *Ceram. Ind.*, **5** [6], 520–21 (1925).—Changes in design of a glass tank at the Carr-Lowrey Glass Co.'s plant at Baltimore, Md., increased the capacity from 12 tons of melted glass, using 13 tons of coal, to 21 tons of melted glass, using 12 tons of coal. The changes were (1) lowering of the crown, 18 inches, (2) lowering of the port, which brought the flame closer to the glass, (3) increasing of port area, which gave a 30% increase of flame area, and (4) increasing of the checker area, about 50%. P. D. H.

Correct decolorizing—dangers of over-decolorizing. L. SPRINGER. *Ceram. Ind.*, **6** [5], 522–23 (1925).—Glasses, low in alkaline fluxes, are easiest to decolorize. Iron will color in proportion to the amt. of alkali in the batch. The minimum amt. of lime is desirable. Potassium glasses are always brighter and less colored than the corresponding sodium glasses. Reducing gases give a poor color to the glass. In decolorizing glass made from salt cake, the effect of the decolorizers is reduced when they are added directly to the salt cake batch. No attempt is made to decolorize glass in continuous tanks because a large part of the glass remains in the bottom of the glass tank. The best crystal glass can be made only in glass pots. For high grade white glass, the iron content of the sand should not be over 0.03%. The iron content of the calcspar should not exceed 0.1% for white glass. P. D. H.

The glass industry and future development. T. C. MOORSHEAD. *Pottery Gaz. and Glass Trade Rev.*, **L581,** 1722–26 (1925).—A model glass melting tank which will be built by the research department of the United Glass Bottle Manufacturers, Ltd., was described by M. before a meeting of the Society of Glass Technology. The design has many novel features and it is thought that the fuel consumption will be cut in half. P. D. H.

Glass-making materials. India. H. C. JONES. India. *Geol. Surv. Records*, **57,** 358 (1925).—Sand of great purity has been obtained in various Indian sandstones; specimens have been examined by Boswell who has reported very favorably on them; some mat. contained 98.95% SiO_2 and another specimen contained as much as 99.29%. Glassworks using local sands or sandstones have been established in many parts of India. Other mat. required in large quantities, such as fire clay, fire bricks of coal are to be had in various parts of India. O. P. R. O.

Autoclave tests on neutral glass surfaces. A. MAURI. *Giorn. Chim. Ind. Appl.*, **7,** 452–65 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 881 (1925).—In all glasses, whether contg. Zn or not, the amt. of alkali liberated by water at 100–120° was proportional to the total alkali in the glass. At higher temps., however, Zn glasses showed much more frosting and scaling, and even when the alk. content of the Zn glass was lower than that of other glasses, the amt. of alkali liberated in the Zn glass was always greater. Zinc content therefore determines the difference in conduct of glasses at low and high temps. Pharmaceutical and surgical glass, which require to be sterilized by heat, should not contain zinc. H. H. S.

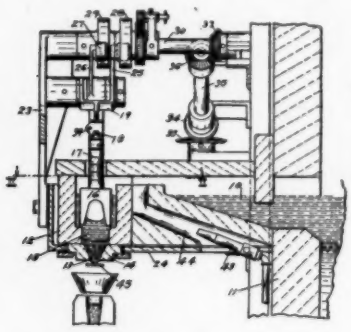
Zinc in scientific glassware. A. MAURI. *Giorn. Chim. Ind. Appl.*, Aug. 1925; *Jour. Soc. Chem. Ind.*, **44,** 1006 (1925).—"Neutral" glasses contg. zinc are suitable for glassware that is not to be heated above 100°C, but are unsuited to use in appliances which have to resist heating, *e.g.* for sterilization, at higher temps. in an autoclave. H. H. S.

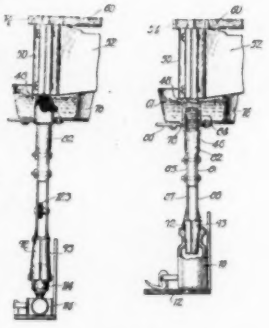
The viscosity of glass. H. LE CHATELIER. *Compt. rend.*, **179,** 517–21 (1924).—A discussion of the results of Washburn, Shelton, and Libman (*C. A.* **18,** 2791). The formula: Log Log $\eta = -Mt + P$ more nearly represents the variation of the coeff. of viscosity as a function of the temp. than the formula used by W. *et al.* No clear relation appears from the results between the compn. of the glasses and the fusing points but the viscosity is certainly such a function. Glass, according to the work of Lafon, changes, like sulphur, from an α- to β-state at a temp. usually between 500° and 600°. The viscosity of the α-form is greater than that of the β, at the transformation point, which leads to opposite effects from those shown by sulphur. (*C. A.*)

The electrical fusion of quartz by the vacuum-compression method. HUGO HELBERGER. *Z. tech. Physik*, **5,** 476–80 (1924).—Description of a suitable furnace together with some properties of quartz. (*C. A.*)

PATENTS

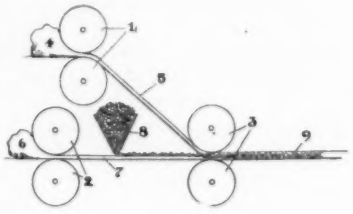
Device for grinding bottles and stoppers. WILLIAM H. RANAGAN. U. S. 1,562,587, Nov. 24, 1925. A pair of grinding plates for a tool of the type described which comprises a pair of sheets forming a frustro-conical surface and adapted to be mounted respectively on their inner or their outer surfaces and attaching tongues for securing said plates to a supporting surface.





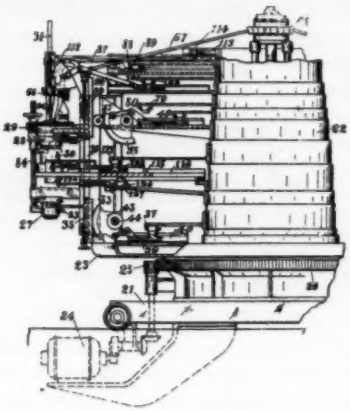
Apparatus for feeding molten glass. LEONARD D. SOUBIER. U. S. 1,563,298, Nov. 24, 1925. A glass feeder comprising, in combination, a receptacle to contain molten glass and provided with a discharge orifice, and means controlling the discharge of glass through said orifice comprising mech. members within the glass adjacent to the orifice, and automatic means for periodically moving said members toward and from each other in a direction transverse to the direction of movement of glass through the orifice, said members when moved toward each other serving to substantially cut off the flow toward said orifice.

Refractory glass plate or articles and method of producing the same. THOMAS A. O'SHAUGHNESSY. U. S. 1,563,584, Dec. 1, 1925. Substantially smooth-surfaced refrac. glass comprising a rolled sheet composed of originally separate layers of glass and interposed granular glass.

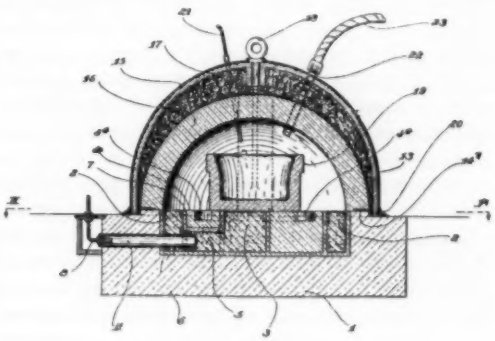


Glass-forming machine. LEONARD D. SOUBIER. U. S. 1,563,933, Dec. 1, 1925. In a glass blowing mach., the combination of

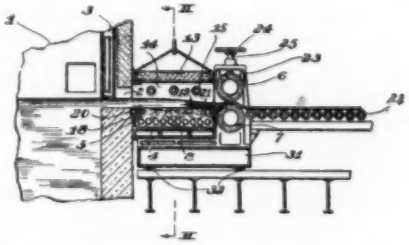
a mold carriage, a blank mold thereon, means to rotate the carriage and bring said mold over a pool of molten glass, a neck mold above and in register with said blank mold, means to draw a charge of glass by suction into the molds, means to lift the molds, means to sever the glass at the lower end of the blank mold, means to form an initial blow opening in the upper end of the blank, means to simultaneously apply air pressure at the two opposite ends of the blank, while in said molds, means to separate the molds by a relative vertical movement thereof, leaving the blank suspended from the neck mold, a sectional finishing mold on the carriage, and means to move it bodily transversely into a position between the separated neck mold and blank mold.

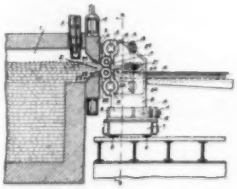


Process and apparatus for melting and fining glass. ALFRED L. HARRINGTON. U. S. 1,564,235, Dec. 8, 1925. A process of producing glass which consists in preliminarily fusing a glass batch in a pot, transferring the pot with the molten glass to an electric fur. and finishing the operation including the fining in such fur.



Process and apparatus for making sheet glass. HALBERT K. HITCHKOCK. U. S. 1,564,240, Dec. 8, 1925. The combination with a glass tank having an outlet slot, of a molten bath of metal in position to receive the glass from the slot of a width greater than said slot, a pair of sizing rolls, at least one of which is driven, located at the forward end of said metal bath, a cover over said bath, means for applying heat intermediate said cover and the bath, and temp. regulating means for said bath.

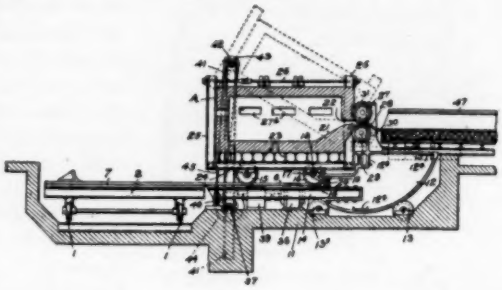




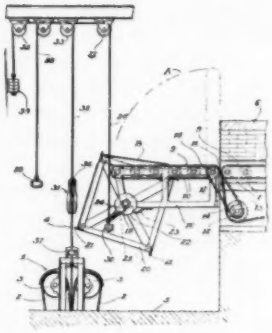
Apparatus for making sheet glass. HALBERT K. HITCHKOCK. U. S. 1,564,241, Dec. 8, 1925. The combination with a glass tank having an outlet slot of a pair of driven forming rolls in opposition to said slot with the pass thereof under the head pressure of the glass in the tank, a pair of supporting rolls engaging said forming rolls along the sides thereof opposite said pass, adjustable swinging arms in which the forming rolls are journalled, pivoted to swing around the axes of rotation of the forming rolls, so as to vary the

width of said pass, means for adjusting said arms and maintaining them in adjusted position, means for driving the supporting rolls, and driving connections between the supporting rolls and forming rolls.

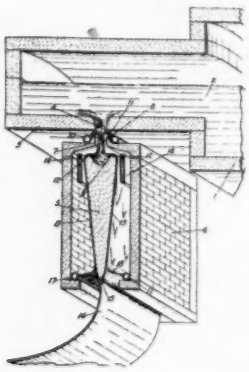
Apparatus for making sheet glass. FREDERICK GELSTHARP. U. S. 1,564,230, Dec. 8, 1925. App. for forming sheet glass, comprising a tank supported on wheels and carrying a glass bath, and having a passage through its wall, a tilting carrier adapted to receive a tank and provided with a pair of water cooled driven rolls in opposition to said passage and a leer for receiving the sheet formed between the rolls, the carrier having its axis of tilting coincident with the axis of rotation of the lower roll.

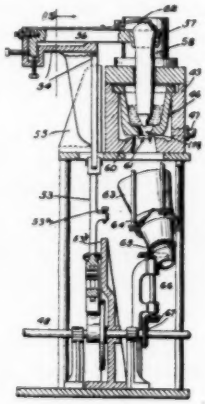


Apparatus for handling glass sheets. WILLIAM OWEN. U. S. 1,564,267, Dec. 8, 1925. The combination with a vertical sheet glass drawing machine, of a counterbalanced clamping device above the machine adapted to engage the upper edge of the sheet cut from the continuous sheet being drawn and move upwardly therewith and give it support during and after the cutting off operation, a driven carrier extending laterally from a position at one side of the machine, and a transfer frame pivoted beneath the end of the carrier adjacent the machine having a plurality of similar faces arranged around the axis of the frame for engaging the flat sides of the glass sheets which are cut from said continuous sheet, supporting means projecting laterally from one edge of each of said faces for engaging the lower edge of said sheets, and means for rotating the frame so that the sheets placed thereon are raised and carried over the carrier and lowered thereon.



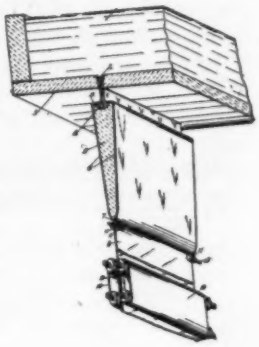
Glass feeding mechanism. THEODORE C. STEIMER. U. S. 1,564,909, Dec. 8, 1925. App. for separating molten glass into mold charges, including a container for the glass having an outlet, an implement projecting into the glass toward the outlet and mounted for movement toward and from the outlet, means for periodically moving said implement toward and from the outlet and means for adjusting the nearest position of said implement to the outlet without changing its position remote from such outlet.





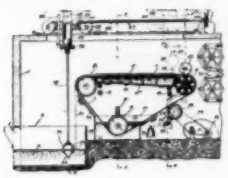
Forming sheet glass. ARTHUR E. FOWLE. U. S.

1,565,319, Dec. 15, 1925. In an app. for producing sheet glass, a receptacle for molten glass having a slot or orifice in the bottom thereof through which a stream of molten glass may flow, means for directly applying heat to the surfaces of this stream as it leaves the slot, a slab positioned below the slot having a longitudinal recess in its upper end for receiving the fluid glass which flows therefrom in thin film form down the converging outer sides of the slab, means for cooling the fluid glass as it overflows the upper edges of the slab, the downwardly flowing glass films uniting at the lower edge of the slab to form a single sheet of glass, and means for reheating the films adjacent the lower edge of the slab.

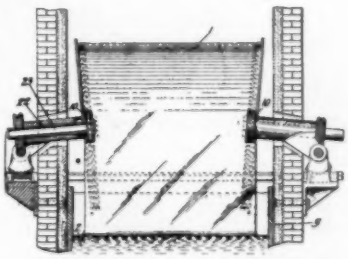


Drawing sheet glass. JAMES C. BLAIR. U. S. 1,565,307, Dec. 15, 1925. In app. for producing sheet glass, a source of molten glass, a slab or forming member down which glass flows from the source, means for drawing this glass from the slab in sheet form, and auxiliary drawing means acting only on the edge portions of the sheet adjacent the line of departure of the glass from the slab.

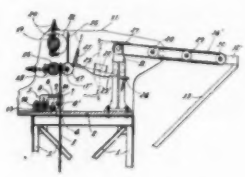
Drawing sheet glass. JOHN C. HENDERSON. U. S. 1,565,363, Dec. 15, 1925. In an app. for producing a continuous sheet of glass, the combination of a receptacle adapted to contain molten glass, and means to draw the glass sheet from this molten glass, including a belt mounted adjacent to the receptacle so as to provide a substantially horizontal sheet-supporting surface, and means for moving said belt so that said horizontal surface continually recedes from the receptacle, a support located beneath the horizontal run of said belt, said support having a cooling chamber therein, and means for circulating a cooling medium through said chamber. In a sheet glass drawing mach. a conveyor upon which the sheet is drawn and flattened, comprising a belt having a metallic outer sheet-supporting surface, and an inner lining of absorbent mat.



Drawing sheet glass. JOHN C. HENDERSON. U. S. 1,565,364, Dec. 15, 1925. In a sheet glass drawing app. means for bending the sheet from one plane to another, comprising means for engaging the sheet edges and drawing them forwardly and outwardly during the bending operation.

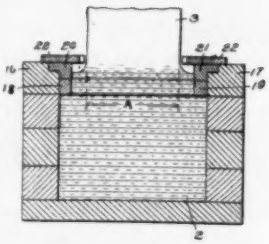


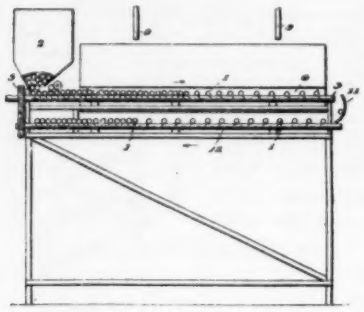
Breaking and transferring mechanism for sheet-glass-drawing machines. THOMAS B. CAMPBELL, JR. U. S. 1,565,710, Dec. 15, 1925. The combination with a vertical glass drawing mach. and a carrier device extending laterally from the line of draw, of a transfer device in the form of a flat sided member mounted for rotation below the carrier and having projecting supporting ledges at the ends of each of the sides of the member.



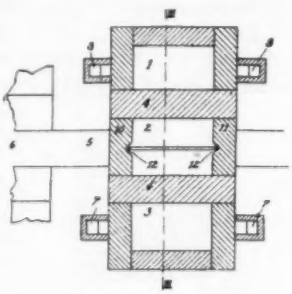
Apparatus for drawing sheet glass. HARRY G. SLINGLUFF. U. S. 1,565,821, Dec. 15,

1925. In combination in glass drawing app., a drawing tank or receptacle for containing a molten bath of glass, means for drawing a glass sheet transversely with respect to the tank with the loci of generation of the edges of the sheets adjacent the sides of the tank, and slotted adjustable shields mounted at the sides of the tank above the surface of the glass and projecting out over the glass at the said loci of generation for regulating the temp. of the glass at such edges.





Machines for making and finishing glass bars, rods, tubes, bottle necks, and the like. VICTOR DURAND, JR. U. S. 1,565,849, Dec. 15, 1925. Means of the character described including feed screws of varying pitch turning in opposite directions to carry articles placed thereon uniformly lengthwise thereof and to separate them at predetermined points in their travel from one another.



Sheet-glass-drawing furnace. GEORGES BRASSEUR and ARISTIDE ANDRIS. U. S. 1,566,181, Dec. 15, 1925. In a sheet glass drawing fur., a molten glass compartment, a heating chamber at each of two opposing sides of said compartment, the remaining sides of said compartment being without direct heating, the non-heated sides of the compartment being formed with V-shaped grooves to receive a plate to start the glass drawing from the compartment in sheet form with the edges thereof in contact with the non-heated sides of the compartment.

Heavy Clay Products

Making brick good and quick. ANON. *Clay Worker*, **84** [2], 107 (1925).—A description of the Consolidated Brick Co. plant at Horseheads, N. Y., making 80,000 common brick a day. Special attention is called to the Autobrik Machine and the automatic pallet loader. The brick are fired in a Haigh 40-chamber continuous kiln 480 ft. long.
F. G. J.

Mammoth face brick plant at Gordon, Ga. nears completion. ANON. *Clay Worker*, **84** [3], 200 (1925).—A description of the new plant and organization of the Georgia White Brick Co. featuring a 360 ft. Harrop tunnel kiln with accommodations for 2 additional units. F. G. J.

Making building brick on Long Island. ANON. *Clay Worker*, **84** [3], 209 (1925).—An illustrated account of the Post Brick Co., Glen Head, Long Island, N. Y. They make a million common brick a month. F. G. J.

Smoke, its cause and cure. W. C. MITCHELL. *Clay Worker*, **84** [5], 408-10 (1925).—A discussion of a method of reducing the smoke nuisance. By burning a smokeless coal, which contains less than 1% sulphur, good results are obtained, with low smoke. Smoke appears to be necessary for making dark colored brick. P. D. H.

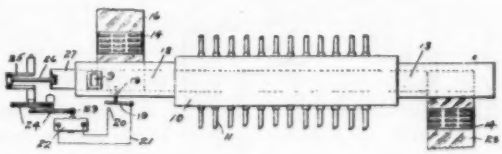
Cheaper hollow tile floors. ANON. *Brick and Clay Record*, **67** [11], 780–81 (1925).—A description of tests run by the Bureau of Standards in coöperation with the Hollow Building Tile Assn. The tests show that hollow tile adds about 50% to the shearing strength in each concrete rib of concrete floor slabs, reënforced in one direction. P. D. H.

Making multicolored bricks. ANON. *Brit. Clayworker*, **34,** 256 (1925).—A certain clay made pale red brick normally but by adding a certain stain to it a deep red brick was produced. The additional cost was 7s. 6d. per 1000 bricks. A fine green color can be obtained on red brick in downdraft kilns by throwing zinc metal, in chippings, on the fire at the end of the firing period. Manganese staining has been used for years and can be practiced if great care is taken that it does not brush off after firing. Brown tints may be obtained in kilns on faces of bricks set in contact in the kiln with a fine layer of ashes between. Changes of tint may be obtained again with red burning clays, by producing a reducing atmos. in downdraft kilns. H. G. S.

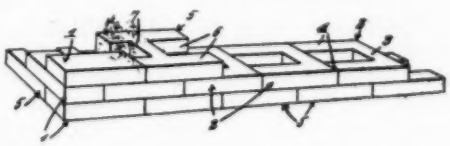
Black cores. ANON. *Brit. Clayworker*, **34,** 256 (1925).—Flaws in ceramic ware are often caused by the intrusion of particles of foreign matter into the bodies during manuf. As a rule, Fe_2O_3, CuO, or particles from the fur. are the sources from which the impurities arise. Outstanding amongst the latter is the defect known as "black cores" mainly attributed to the decompn. of pyrites. These cores have the form of small cone shaped hollows containing a fraction of the pyrites in the bottom. In order to prevent the formation to these flaws, ventilation should be good, and htg. should be carried out slowly during the oxidation period, particularly as the temp. approaches 1000°C. If the whole of the C present has not been oxidized when the temp. has reached 1000°C, Fe pyrites, which, under ordinary conditions decompose rapidly at 850°C, will most likely act with the clay forming black core. The formation of this defect is less frequent in dry pressed bricks than in the plastic made of fine texture. The presence of large grains of calcareous matter also produces flaws. The method recommended to prevent black core applies also to preventing calcareous flaws. H. G. S.

PATENTS

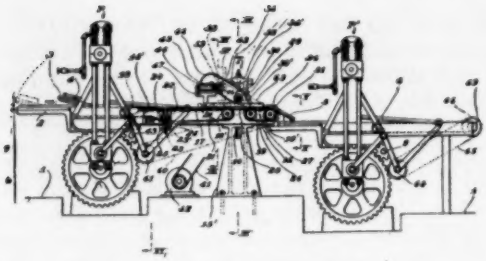
Apparatus for firing brick. THOMAS STANLEY CURTIS. U. S. 1,562,441, Nov. 24, 1925. A kiln comprising a highly-heated chamber, means for localizing the heat in said chamber, means for conducting the work to be treated at a predetermined speed past the high temp. point, means for automatically introducing the work into the heating chamber through an opening in the side thereof, means for automatically and intermittently feeding the work as introduced at a predetermined speed to the fur., and means for automatically conducting the treated work from the fur.



Building block and wall. BENJAMIN F. HAYDEN. U. S. 1,564,568, Dec. 8,1925. A wall made up of H-shaped blocks and U-shaped blocks laid in alternating courses, and oblong blocks disposed at right angles to each other at a corner of the wall, the oblong blocks coöperating with the courses to dispose the H-shaped and U-shaped blocks of adjoining courses in break-joint order and to align the transverse parts of the U-shaped and H-shaped blocks vertically.

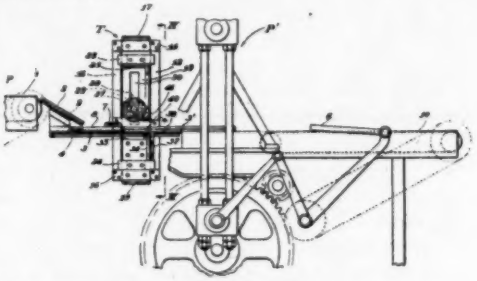


Brick machine. GEORGE B. HANEY. U. S. 1,565,738, Dec. 15, 1925. A brick mach.

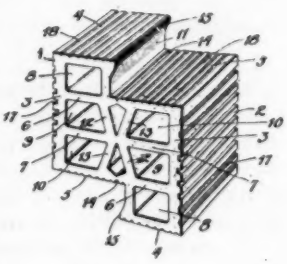


comprising in coördinated relation a press, a brick trimmer, a repress, and a brick conveyor, the trimmer being positioned above the conveyor and adapted to remove excess mat. from the tops of bricks passing thereunder, and the conveyor comprising a a brick-supporting horizontally-moving member passing under the cutter in positively spaced relation thereto.

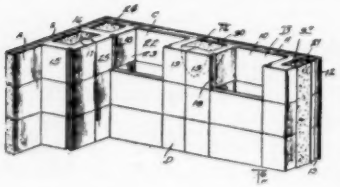
Trimming mechanism for brick machines. GEORGE B. HANEY. U. S. 1,565,739, Dec. 15, 1925. In combination with a press having a feed table and means for feeding the bricks into the press, of a trimmer mounted on the table, the trimmer being so disposed relatively to the press and table that the said feeding means forces the bricks through the trimmer prior to reaching the press and during its continued movement in the same direction to the press.



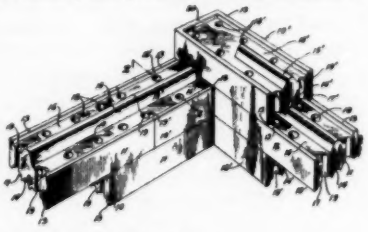
Hollow tile. RICHARD S. REQUA. U. S. 1,565,959, Dec. 15, 1925. A hollow tile having outer walls and interior webs aligning with certain of the said walls, and internal webs joining the upper outer wall at points intermediate the side walls and converging towards the center of tile and similar internal webs joining the bottom outer wall at points intermediate the side walls and converging towards the center of the block.



Block and wall structure. TASKER HENDERSON. U. S. 1,566,211, Dec. 15, 1925. A structure forming a thin wall with spaced pillar scomprising courses of blocks each having at its ends lateral extensions provided in their upper parts with pockets tapered toward the ends of the block, the pockets of the successive blocks in each course being adjacent to each other and having a plastic binder and filler.



Wall construction. John F. RYAN. U. S. 1,566,228, Dec. 15, 1925. In a wall construction, a plurality of identical corner blocks disposed at right angles to each other, a seat provided on each of said blocks to receive an overlapping portion of the next adjacent block, runner blocks, and interlocking means between said corner blocks and said runner blocks.



Refractories

An eighteen months' high temperature test on refractory test specimens. F. H. RIDDLE and A. B. PECK. *Jour. Amer. Ceram. Soc.*, **9** [1], 1-22 (1926).—Advantage was taken of an 18 months' continuous run of the Dressler Kiln of the Champion Porcelain Co. firing to between cones 17 and 18, to observe the effect of the temps. and the gas conditions in various parts of the kiln upon a large number of standard bodies and exptl. mixes. The kiln and conditions within it are briefly described, as well as the types of bodies used. The observed changes in outward phys. properties of the bodies are supplemented by petrographic-microscopic examns. in order to det. or explain the reasons for the behavior of the bodies. Three instances of the production of deposits of artificial minerals formed in the kiln during firing are also described and explanations for their occurrence are given.

Load tests for refractories. ANON. *Can. Chem. Met.*, **9** [10], 227 (1925).—A short account of the fund. study of load tests carried out at the Ceramic Station of the U. S. Bur. of Mines. F. G. J.

Fire bricks for furnaces using pulverized fuel. ANON. *Brit. Clayworker*, **34**, 255 (1925).—Speaking generally, those bricks which will best resist the action in a fur. using pulverized fuel, are ones with close surface and so accurate a shape that they can be laid with the thinnest possible joints. Beyond this, silica bricks—if they do not spall—are usually more durable than fireclay bricks, but no general statement such as this should be understood as excluding all fireclay brick. A method of comparing the resist. of different bricks to pulverized fuel, as devised by Steinhoff of Dortmund, is described. H. G. S.

Molding sands and their behavior under high temperatures. A. L. CURTIS. *Iron and Steel Inst.*, Sept. 1925; *Jour. Soc. Chem. Ind.*, **44B**, 810 (1925).—From the invest. of a large number of molding sands, it is considered, rather contrary to present views, that the value of ultimate chem. anal. cannot be over-estimated for checking the stability of natural or artificially compounded sand for this purpose. Frequent control tests embracing anal., fusibility, washing, grading, permeability and dry crushing are necessary owing to the great variation in natural argillaceous sands. The variation in bulk over a period of six months is shown in the figures: Silt and clay 17–54%, SiO_2 88–81%, Al_2O_3 4–9.7%, permeability 137–55%. The behavior of natural sands and sand mixts. at high temps. were observed by means of a micro-telescope focussed on the sample heated by an oxy-coal-gas flame; it is illustrated by photographs. H. H. S.

Refractory problems in non-ferrous melting. G. F. HUGHES. *Fuels and Fur.*, **3** [11], 1223–24 (1925).—Detailed description of the method of lining various types of elec. furs., the method of preheating them preparatory to introducing the metal charge, and the compns. of satisfactory cements for these linings. It is pointed out that cracking of the linings after vitrification was a problem. Two ways of solving this problem are suggested. R. M. K.

A high temperature fuel furnace for crucibles. WM. MASON. *Fuels and Fur.*, **3** [11], 1257–58, 1276 (1925).—A detailed explanation and description of a fuel-fired crucible fur. for melting wrought iron and other semi-refrac. metals is given. Cuts are given showing the design of this fur. Forced draft is used and the air is preheated. R. M. K.

Ceramics at the Bureau of Standards. ANON. *Chem. Met. Eng.*, **32**, 867–69 (1925).—An outline of the work now proceeding at the Bureau of Standards, on brick for rotary cement kilns, brick for stoker-fired settings, resist. of tank blocks to glass attack, and sagger problems. M. E. M.

The manufacture of carborundum. I. STEWART. *Chem. Eng. Min. Rev.*, **18,** 205–07 (1925).—A non-technical description of the plant and process. M. E. M.

Bauxite. India. C. S. FOX. *India Geol. Surv. Records*, **57** (1925).—Workable occurrences of bauxite exist in several places in India. F. reviews prospects, which he states are rather discouraging for India. He classifies bauxite under (1) the Mediterranean type and (2) the Tertiary type. Under the former class are included the bauxites of Spain, France, Italy, Jugoslavia and Rumania, types which seldom contain more than 14% of combined water and indicate a certain degree of dehydration. The latter class includes most of the bauxites of America, Africa, India and Australia; these deposits appear to be of a geologically younger type and average a water content of 22% to 30% with a somewhat lower alumina content (54%) than the Mediterranean type. For commercial purposes bauxites are classified: (a) Normal bauxite. Fair quality with 50 to 60% alumina, and high-grade ore with over 60% of alumina. Total impurities not to exceed 20%, excluding combined water content, the chief impurities, ferric oxide, silica and titania each not to exceed 5%. (b) Siliceous bauxite. To have upwards of 55% alumina and not more than 20% impurities excluding water. Silica from over 5 to about 20%; ferric oxide less than 5%; titania up to 5%. This class of ore is most frequently used for chem. purposes or the prepn. of alum and other aluminum salts. (c) Titaniferous bauxite. The alumina to average 55% and the total impurities excluding combined water not to exceed 25%. Titania above 7%; silica less than 5%; ferric oxide not to exceed 10%. These bauxites are rare except in India but have a great future before them owing to the valuable nature of the titaniferous slime which can be obtained as a by-product when the ore is purified by the Bayer process. (d) Red or ferruginous bauxite. Alumina content to be upward of 52%; total impurities not to exceed 25%; ferric oxide between 10 and 25%; silica less than 5%; titania normally less than 5%. This variety of bauxite is most commonly used by aluminium reduction companies. F. deals with quarrying and mining of bauxite; calcination; and the manuf. of alumina and aluminium. He further discusses the uses of bauxite for chem. purposes; for petroleum purification; for decolorization of sugar; bauxite cements; bauxite for abrasive purposes and bauxite refracs. He discusses bauxite specifs. and contracts, and states that if due attention were paid to the sampling and chem. anal. of bauxite, it is probable that considerable quantities of low grade ore could be mixed with particularly rich mat. and maintain thereby shipments of uniform quality. He concludes with reference to Indian occurrences of bauxite described in *Mem. of Geol. Surv. of India*, **49** (1923;) and to an article pub. in *Mining Mag.*, Feb. 1922, and to an article on the aluminium industry, *Mining Jour.*, Oct. 28 and Nov. 4, 1922. O. P. R. O.

Effect of a few typical refractory clays on the behavior of chamottes at high temperatures. W. STEFER. *Ber. deut. keram. Ges.*, **3,** 250–56 (1922); *Chimie et industrie* **12,** 1066 (1924). (*C. A.*)

The thermal conductivity of refractory materials. P. GILARD. *Rev. universelle mines*, **4,** [7], 34–50 (1924).—A review and discussion of the phys. principles of heat condy., its methods of detn. and data on the condy. of various materials at different temps. A bibliography of 38 references is included. (*C. A.*)

A Washington magnesite plant. G. H. YOUNG. *Eng. Mining J.-Press*, **119,** 440–42 (1925). (*C. A.*)

Refractories for gas retorts with special reference to silica. W. EMERY. *Gas J.* (Suppl. July 9, 1924) 3–16.—The analyses and the true and apparent sp. gr., after expansion and contraction of several silica and siliceous bricks have been detd. The transfer of heat is more rapid by silica than by fireclay refracs. at temps. above 1000° though the reverse may be true at lower temps. The infiltration of C into the pores of the mat. invalidates lab. meas. made on the unused refrac. Silica refracs. will withstand

higher temps. under load than will fireclay and are more resistant to corrosion by salt. Silica retorts withstand abrasion satisfactorily. The high reversible thermal expansion of silica and the care required in heating up silica settings are discussed. The necessity of completing as much conversion of the quartz and as great a shrinkage of fireclay as possible in the kiln is emphasized. Fire clay is less liable to spall than silica, but many users of the latter have found no difficulty due to spalling on shutting down. The results of the examn. of several vertical and horizontal retorts after use are described. A. Scott in an appendix describes the microstructure of the mats. examd. (*C. A.*)

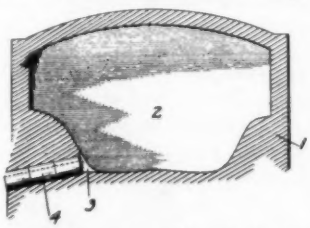
PATENTS

Refractory material and method of producing the same. WILLIAM A. HARTY. U. S. 1,563,853, Dec. 1, 1925. The method of producing fused substantially pure silica consisting in fusing sand in an electric fur. beneath an isolating layer of amorphous or crystalline silicon carbide.

Process of separating the constituents of mineral silicates. SHERMAN W. SCOFIELD and JOHN B. LA RUE. U. S. 1,563,875, Dec. 1, 1925. In the process of converting potash-feldspar into alkali-metal silicate and aluminate by means of converting crystalline feldspar into amorphous feldspar and heating a mixt. of said amorphous feldspar and a soln. of caustic alkali in a closed vessel, the method of completely converting the feldspar into water-soluble compds. consisting in, utilizing, for the alkali digestion step, substantially 90% caustic alkali in amt. from 1 to 2 times by weight of the feldspar and an amount of water substantially equal to the feldspar, together with a pressure of substantially 300 lbs. per sq. in. and a temp. of substantially 270°C, the treatment being continued until substantially all the normally insoluble constituents are fused, and then adding more water.

Silica-brick pallet cleaner. MANCE CANTRELL. U. S. 1,564,199, Dec. 8, 1925. In a silica brick pallet cleaner, a shank, a head carried by one end thereof and provided with a plurality of parallel grooves, elongated scraping blades received in the grooves and having their ends projecting a relatively great distance beyond the head and disposed in overlapping relation, and fastening elements passing through the head at opposite sides thereof and engaging the blades to hold the same in position in the grooves and permitting the longitudinal adjustment of the same, the shank being adapted to be received in a rotary tool holder whereby to rotate the blades over the surface of the pallet to scrape silica therefrom.

Unfired refractory brick. ROBERT YOUNGMAN. U. S. 1,564,394, Dec. 8, 1925. An unfired refrac. brick composed of calcined magnesite, chrome ore, and sodium silicate.



Article for lining tap holes of furnaces. HENRY G. FRERICHS. U. S. 1,565,084, Dec. 8, 1925. A monolithic magnesite tap-hole refrac. for furs. and of tubular cross-section.

Refractory cement with a base of zirconium ore. FREDERIC CHARLES F. LE COULTRE. U. S. 1,565,472, Dec. 15, 1925. A refrac. cement having a base of zirconium ore comprising a mixt. of substantially pure oxide of zirconium, an organic binder, an inorganic binder and finely crushed powder of zirconium ore.

Refractory material from zirconium ore. SOC. D'ETUDE DES AGGLOMERES. Brit. 223,573, Oct. 17, 1923. A Zr ore is heated to a high temp. in an elec. fur. and then discharged into H_2O contg. 0.1% H_2SO_4. After crushing the raw mat. is agglomerated

with mixed org. and inorg. binders, *e.g.*, with 0.5% dextrin or tar and 0.25% conglomerates and dolomites. The Fe ore contains up to 59% Fe, the Mn ore, 36% Mn, with small amts. of S, P, and SiO_2.

Fused silica. QUARTZ AND SILICE. Brit. 224,163, Nov. 2, 1923. SiO_2 is melted in direct contact with a refrac. mold formed of conducting mat. such as graphite by the induction of high-frequency elec. currents. Brit. 224,164 specifies melting SiO_2 by this method in a crucible and then shaping the material, *e.g.*, into rods, by extrusion or drawing.

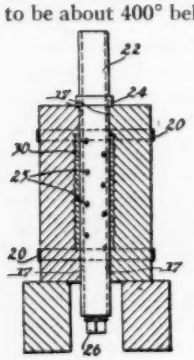
White Wares

New machine for determining strength of vitrified china ware. ANON. *Pottery Glass and Brass Salesman*. **32** [9], 13 (1925).—A mach. for detg. the strength of vitrified china ware or of unfinished pieces by chipping and impact has been developed at the Bureau of Standards. It consists of a swinging hammer. A 4-oz. hammer is used for impact test, 6-oz. for chipping. The mach. has increased accuracy and flexibility. F. G. J.

Many new ideas seen in modern Ohio pottery. ANON. *Ceram. Ind.*, **5** [6], 536–44 (1925).—A description of the Steubenville (O.) Pottery Co.'s new plant is given. P. D. H.

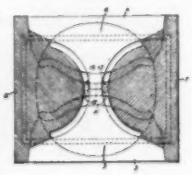
Sanitary ware and its production. ANON. *Clay Worker*, **84** [6], 475–80 (1925).—A history of the Fords Porcelain Works at Perth Amboy, N. J., together with a description of the mfg. processes and products. P. D. H.

Thermal expansion and some other physical properties of fine porcelain as affected by composition and firing temperature. H. KOHL. *Ber. deut. keram. Ges.*, **3**, 303–44 (1922); *Chimie et industrie*, **12**, 1067–68 (1924).—In the system kaolin-feldspar, a 30% feldspar paste had a smaller expansion than kaolin at low temps., the expansion being nearly proportional to the contraction with rise of temp. Feldspar behaves similarly in a clay-quartz-feldspar system, as long as its effect is not neutralized by that of quartz. Expansion increases to cone 5 and then decreases, presumably because of soln. of the SiO_2 in the fused feldspar with increase in temp. The effect of quartz is very important: between 10° and 500° its expansion predominates, and varies in proportion to the quantity added. Between 500° and 600° the increase in vol. due to transformation of α- into β-quartz results in a sudden increase in expansion. The contraction of β-quartz is apparent after transformation at 950°. The action of quartz on contraction and porosity increases with its fineness. Chalcedony (as pebbles) behaves like quartz. When previously fired to cone 14 it is converted into cristobalite. Addn. of CaO increases the expansion coeff. The enamel was fissured when the frit had a lower expansion coeff. than the enamel; and it scaled when the frit had an appreciably higher expansion coeff. than the enamel. The transformation of quartz at 575° seems to have no effect on the behavior of the enamel. The limits of possible deformation due to softening seem to be about 400° below the m.p. (*C. A.*)



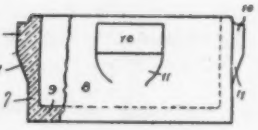
PATENTS

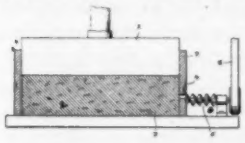
Method of and means for casting articles. CHARLES CLAFLIN RAND. U. S. 1,564,274, Dec. 8, 1925. The method of casting an article, which consists in directing a slip against the wall of a mold cavity from a position within the cavity.



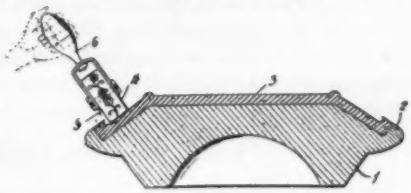
Mold for casting insulators. MARSDEN H. HUNT. U. S. 1,565,460, Dec. 15, 1925. A mold for forming insulators of the link type comprising a structure having core portions disposed in crossed spaced relation to form the interlinked openings thereof and constructed for withdrawal from the insulators that are molded therein.

Sagger. LORENZO C. BUCKLEY. U. S. 1,566,070, Dec. 15, 1925. A one-piece sagger having circumferentially-extending integral bosses spaced at intervals around the side walls of the sagger, and having a vertical extent substantially less than the depth of the sagger, said bosses serving as spacers between the saggers of adjacent bungs to insure both vertical and horizontal circulation channels for kiln gases during firing.





Brickmaking means. REUBEN F. ROSS. U. S. 1,566,126, Dec. 15, 1925. Brick making means comprising a press box adapted to receive clay or other stock and pressure exerting means and having a vent for surplus clay or other stock, in combination with cut-off means exterior of the box and arranged adjacent to the said vent and adapted to operate on stock that exudes through the vent; the said cut off means being in the form of an auger and being provided with a driving connection whereby it is adapted to convey stock away from the vent.



Method of and apparatus for decorating articles of plastic material. JOHN EDWARD MILLER. U. S. 1,566,158, Dec. 15, 1925. In the method of decorating articles made of plastic material, forming the article mold by providing a jigger-head with a layer of plastic mat. shaped to form the article, and then impressing a decoration into the surface of said plastic mat.

Equipment and Apparatus

The drying process. RALPH K. HURSH. *Clay Worker*, **84** [5], 380-83 (1925).—Requirements for the safe drying of brick are given. Special equipment for testing clays as to their drying properties is described. P. D. H.

Screening. O. W. DUNLAP. *Clay Worker*, **84** [5], 393 (1925).—A description of the working of the "Perfect Clay Screen" for screening brick clay is given. P. D. H.

Recording pyrometer. ANON. *Fuels and Fur.*, **3** [11], 1283 (1925).—The new Charles Englehard type S recorder is described. R. M. K.

Optical pyrometers. W. E. FORSYTHE. *J. Opt. Soc. Am.*, **10**, 19-37 (1925).—A brief practical manual, dealing especially with screens, calibrations, brightness- and true-temps. (*C. A.*)

Progress in chemical equipment. ANON. *Ind. Eng. Chem.*, **17**, 1002–13 (1925).—Mentions large stoneware tanks, Merco-Knight lubricated stoneware cocks, porous carboy stoppers, pressure-cast stoneware, industrial Pyrex equipment, general progress in enamel ware, rubber-lined centrifugal pumps, Alcumite, Duriron double-acting pumps, use of welding in fabricating equipment, specially ventilated and non-ventilated motors, Shriver pressure diaphragm pumps, Hardinge clarifier-thickener, Dorr washer-thickener, use of thickeners for recovering blast-furnace flue dust, Hardinge batch mill, Sturtevant slow-speed air separator, Hardinge rotary classifiers, Krause rotating-disk spray driers, Carrier humidifiers for driers, spray burners for S, pressure plants for H_2SO_4 on the small scale, Schmiedel H_2SO_4 process for gases low in SO_2, Bayer furnace for HCl, Badger-Stafford wood-distn. process, Badger horizontal film evaporator, Swenson-Pyrex glass evaporator, Swenson-Yaryan evaporator, evaporators for salts with inverted soly. curves, Swenson-Walker crystallizer and dewaterer, Swenson-Kipper drier, Buffalo

atm. drum drier, Buffalo water distiller, Bethlehem-Frederking app. with coils cast in the walls, and the Carrier low-pressure refrigeration system. (*C. A.*)

PATENTS

Recording meter. RICHARD P. BROWN. U. S. 1,564,518, Dec. 8, 1925. In a recording instrument comprising a meter pointer movable in a horizontal plane and means for intermittently depressing the latter, the improved means for supporting and advancing a record strip comprising a feed roll and guide of inverted trough-like shape above the feed roll and forming a straight edge over which a record sheet is drawn sharply downward by the feed roll, said straight edge and pointer coöperating to form a record impression on the record strip when the pointer is depressed.

Meter. RICHARD P. BROWN. U. S. 1,564,519, Dec. 8, 1925. In an elec. recorder, the combination with a sensitive elec. meter having a deflecting pointer, of a housing for said meter comprising a base adapted to be secured to a supporting structure, a member normally extending across the front of said base and having said meter secured to its rear side and being formed with a slot through which the meter pointer projects, recording mechanism coöperating with the meter pointer and secured to the front side of the last mentioned member, and a hinge connection between said base and said member permitting the latter to be swung away from the base to render said meter accessible.

Kilns, Furnaces, Fuels and Combustion

Operation of gas producers. F. S. BLOOM. *Fuels and Fur.*, **3** [11], 1227–30 (1925).—A discussion of the factors detg. the capacity of a gas producer and the quality of gas produced. The opern. of a gas producer is greatly influenced by its gas supply. Mech. precautions have been taken to make possible the least resist. to air flow by keeping the bed thin and free from clinkers. However, mech. features have been given first consideration. Most gas producers when operating on high clinkering coals can be operated with much success when using only .085 lb. of moisture per pound of air supplied. R. M. K.

Economy and dependability in kiln banding. B. J. GALLAGHER. *Clay Worker*, **84** [5], 411–12 (1925).—Reasons for good banding of kilns and methods of purchasing kiln bands, in order to save money, are given. P. D. H.

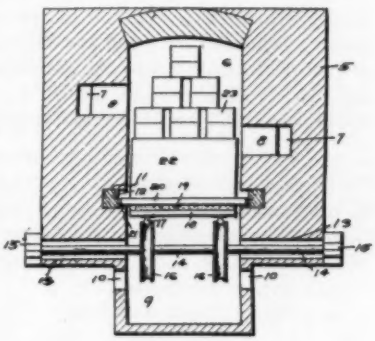
Advantages and disadvantages of the tunnel kiln parts. ANON. *Tonind. Zeit.; Clay Worker*, **84** [2], 116 (1925).—An argument about pressure gas, clear or raw gas, and direct or indirect cooling. See *Ceram. Abs.*, **4** [7], 199 (1925). F. G. J.

Latest developments in the construction of electrical porcelain kilns. F. A. J. FITZGERALD. *Can. Chem. and Met.*, **9** [12], 271 (1925).—An address before the Toronto Sections of the Society of Chemical Industry and of the Canadian Institute of Chemistry. The first public announcement of the electrically heated kiln. The outside is refrac. brick, the lining carborundum. The resistor consists of a series of carbon plates so placed as to touch each other at only a relatively small section of their sides. The resistor is placed at the top of the heat chamber proper and the ware to be fired enters and leaves the kiln on cars. Porcelain spark plugs and glazed ware can be fired at the same time. The total cost of firing spark plugs in the kiln is 63 cts. per thousand. F. G. J.

Tests with the "Becker" oil furnace. E. MOSER. *Ber. deut. keram. Ges.*, **3**, 344-47 (1922); *Chimie et industrie*, **12**, 503–4 (1924).—Tests at the national porcelain works at Charlottenburg with the Becker furnace (described in detail) showed relative costs of 405 to 450 for oil and wood, resp. The time of firing was reduced from 3 to 2.5 hrs., and the cost of labor is lower with oil than with wood. (*C. A.*)

PATENTS

Traveling support for kilns. WILSON L. BURLEY. U. S. 1,564,935, Dec. 8, 1925. A kiln chamber provided in its side walls with longitudinal grooves, the kiln chamber being continuous from points above and below the grooves, the bottom of the chamber continuing in a pit, said pit having side walls provided with air circulating openings and the chamber having transverse openings above the air circulating openings and beneath said grooves, said transverse openings leading into the pit and adapted to receive cooling air therefrom, transverse shafts extending through the transverse openings, wheels carried by the transverse shafts, a table arranged beneath the transverse grooves and above the wheels, rails secured to the lower surface of the table and engaging the wheels, a refrac. slab mounted upon and insulated from the table and projecting outwardly beyond the same and entering the grooves, and heat insulating mat. within the grooves, the grooves and slab forming seals.



Geology

Vast wealth stored up in Georgia clay. R. T. STULL *Clay Worker*, **84** [3], 201 (1925).—An account of the clay resources of Georgia and of Wilkinson county in particular, a history of clay mining in Georgia and a theory as to its origin. The uses of this clay for fire brick, face brick, white ware and filler, etc., are described. Account is given of the different mines and refining plants and of the possibilities ahead. F. G. J.

Potash in Poland. ANON. *Jour. Soc. Chem. Ind.*, **44**, 1121 (1925).—Potash beds, 80 ft. thick, of excellent quality, occur at Stebnik. Drillings to the S. E. of Kalusz also show deposits in this district. H. H. S.

Barytes in Ireland. ANON. *Jour. Soc. Chem. Ind.*, **44**, 1122 (1925).—Deposits occur in the Sligo district. Operations are beginning at Glencar, near Sligo. H. H. S.

Mineral production. India. ANON. *India Geol. Surv. Records*, **58**, Pt. 3 (1925).—Mineral production of India during 1924. O. P. R. O.

Corundum. India. ANON. *India Geol. Surv. Records*, **57** (1925).—Corundum is widely distributed throughout the Mysore State; and is known to occur in the Khasi Hills of the Nongstoin State; in the Madras Presidency and in Rewah State. The mines have not been worked since 1920–21. O. P. R. O.

Pyrites. India. ANON. *India Geol. Surv. Records*, **57** (1925).—Pyrite seems to be widely distributed throughout the Indian Empire, but has only in recent years been seriously exploited. O. P. R. O.

Chemistry and Physics

The ternary system sodium metasilicate-calcium metasilicate-silica. G. W. MOREY and N. L. BOWEN. *Jour. Soc. Glass Tech.*, **9** [35], 226–64 (1925).—This paper describes one of the thermo-chemical studies for which the Geophysical Laboratory is famous. This study has as its chief motive the attainment of exact knowledge in regard to the ordinary lime-soda glass of commerce. The field is represented by the compns. 45% CaO, 45% Na_2O, 100% SiO_2 as end members of the triaxial field. The method of studying the equilibrium relation between glass and the crystalline phases used throughout

the work was that of quenching introduced into the study of silicate mixts. by Shepherd in 1909. The accompanying diagrams show the equilibrium relations in the field studied. The following new compds. were found and their compns. determined: the compd $2Na_2O$, CaO, $3SiO_2$ which melts incongruently forming a liquid richer in Na_2SiO_3 and Na_2O, 2CaO, $3SiO_2$ and the compound Na_2O, CaO, $3SiO_2$, which has a congruent melting point at 1284°; and the compd. Na_2O, 3CaO, $6SiO_2$ which melts incongruently at 1045°C, forming a mixt. of wollastonite and glass containing approx. 15% CaO and 67% SiO_2. These compds. are all characterized by a large amt. of dissociation in the liquid phase. A table of the crystallographic and optical properties is given.

Invariant Points

Phases	Compounds (Type)	Temp.
SiO_2 : β-quartz	Inversion	870°C
SiO_2 : tridymite	Inversion	1470
SiO_2 : cristobalite	Melting	1710
β-CaO, SiO_2 : wollastonite	Inversion	1180
α-CaO, SiO_2 : pseudo-wollastonite	Melting	1540

Invariant Points

Phases	Compounds (Type)	Temp.
Na_2O, $2SiO_2$	Melting	874°C
Na_2O, SiO_2	Melting	1088
$2Na_2O$, CaO, $3SiO_2$	Decomposition into Na_2O, 2CaO, $3SiO_2$ and liquid 11, 55 CaO	1141
Na_2O, 2CaO, $3SiO_2$	Melting	1284
Na_2O, 3CaO, $6SiO_2$	Decomposition into β-CaO. SiO_2 and liquid 15% CaO, 67% SiO°	1047

Binary Invariant Points

System Na_2O, SiO_2-CaO, SiO_2

Phases	Type	Composition per cent		Temp.
Na_2O, SiO_2+$2Na_2O$, CaO, $3SiO_2$	Eutectic	3.0	CaO	1060
$2Na_2O$, CaO, $3SiO_2$+Na_2O, 2CaO, $3SiO_2$	Decomposition	11.5	CaO	1141°
Na_2O, 2CaO, $3SiO_2$	Melting point	31.61	CaO	1284
Na_2O, 2CaO, $3SiO_2$+CaO, SiO_2	Eutectic	33.0	CaO	1280

System Na_2O, $2SiO_2$-Na_2O, 2CaO, $3SiO_2$

Na_2O, $2SiO_2$+Na_2O, 2CaO, $3SiO_2$	Eutectic	3.0	CaO	862

Ternary Invariant Points

Na_2O, SiO_2+Na_2O, $2SiO_2$ +$2Na_2O$, CaO, $3SiO_2$	Eutectic	1.8 60.7	CaO SiO_2	821
Na_2O, $2SiO_2$+$2Na_2O$, CaO, $3SiO_2$ +Na_2O, 2CaO, $3SiO_2$	Reaction point	2.0 61.4	CaO: SiO_2	827
Na_2O, $2SiO_2$+Na_2O, 2CaO, $3SiO_2$ +Na_2O, 3CaO, $6SiO_2$	Reaction point	5.2 70.7	CaO: SiO_2	740
Na_2O, $2SiO_2$+Na_2O, 3CaO, $6SiO_2$ + quartz	Eutectic	5.2 73.5	CaO: SiO_2	725
Na_2O, 2CaO, $3SiO_2$+Na_2O, 3CaO, $6SiO_2$+wollastonite	Reaction point	14.5 66.5	CaO: SiO_2	1030°

Temperatures of Primary Crystallization of the Glasses of Figure 8.

Glass No.	Composition		Temperature	Primary Phase
	Na_2O	SiO_2		
1	25.3	74.1	825°C	Quartz
3	23.0	74.1	825	Quartz

4	21.5	70.1	825	Quartz
5	20.8	73.8	800	Quartz
6	19.4	73.2	880	Na_2O, 3CaO, $6SiO_2$
7	17.2	74.4	930	Tridymite
8	16.0	75.0	1040	Tridymite
9	14.9	75	1080	Tridymite
10	14.2	74.6	1095	Tridymite
11	13.0	74.9	1150	Tridymite

R. M. K.

A deformation study of various aluminosilicates and borosilicates. KAI CHING LU. *Jour. Amer. Ceram. Soc.*, **9** [1], 30 (1926).—A brief review of the past literature on the thermochemical study of silicates, aluminosilicates and borosilicates was prepd. The present study includes the development of 5 ternary "deformation eutectics," which had the following compns. and deformation temps.

Molecular Formula

PbO	: 0.254 Al_2O_3	: 1.91 SiO_2	Na_2O	: 1.29 B_2O_3	: 1.73 SiO_2
ZnO	: 0.225 Al_2O_3	: 0.906 SiO_2	K_2O	: 2.11 B_2O_3	: 2.585 SiO_2
PbO	: 0.238 B_2O_3	: 0.78 SiO_2			

Approximate Deformation Temp. in °C:
650, 1360, 415, 570, 655,

Cones were made and deformation was studied in the same manner as used with standard pyrometric cones. All eutectics developed are within the 2½ mols. per cent limit. Combination of eutectics were also made but no further lowering of temp. was noticed. The results were discussed with special stress laid upon the relation between the various eutectics.

Mineralogy of clay-I. The mineral constituents of clay. J. SPOTTS MCDOWELL. *Jour. Amer. Ceram. Soc.*, **9** [1], 55 (1926).—A review of the literature on the microscopic examn. of clays. **Rational Analysis of Clay-II.** *Ibid.*, **9** [1], 61 (1926).—A review of the literature on the rational anal. of clays. The methods of detg. the rational anal. are shown to be inaccurate.

The structure of quartz. W. H. BRAGG. *Jour. Soc. Glass Tech.*, **9** [35], 273–82 (1925).—Previous work has shown that the unit cell of the crystal quartz contained the substance of three molecules of silicon dioxide so arranged in spiral fashion that each could be derived from its neighbor by a rotation of 120° around the crystal axis accompanied by a translation of 1.79 Angstrom units along the axis. In this paper the structure of quartz is explained from theoretical considerations. R. M. K.

The plasticity of clay. W. D. BANCROFT and L. E. JENKS. *Jour. Phys. Chem.*, **29** [10], 1215–16 (1925).—The prob. was to find out whether any electrolyte would make and keep a non-plastic clay plastic when added in moderate amts. As a non-plastic clay kaolin was used. It was found that addition of about .25% of lithium salt, usually lithium chloride, together with a little NaCl gave kaolin of a higher plasticity than any of the ball clays tested. No firing expts. were made. No connection was found between the plasticity of clays and their lithium content and it is probable that the plasticity of clay is due to the combined effect of humus and some electrolyte. E. J. T.

Plasticity. E. C. BINGHAM. *Jour. Phys. Chem.*, **29** [10], 1201–4 (1925).—This paper was the introduction to Plasticity Symposium, Lafayette College, October 17 (1924) and defined plasticity and explained the difference between plasticity and viscosity.

E. J. T.

Aqueous solutions of sodium silicates. R. W. HARMAN. *Jour. Phys. Chem.*, **29** [9], 1155–68 (1925).—In this invest. the system Na_2O-SiO_2 at 25°C has been studied from the point of view of: (1) condy.; (2) transport numbers; (3) hydrolysis; (4) sodium ion activity; silicate ion; (6) lowering of the vapor press. and of f. p. (7) heterogenous equilibria. Summary: (1) Cryst. Na_2SiO_3 has been prepd., and from a soln. of this salt, various other ratios Na_2O: SiO_2 have been prepd. by removing the alkali electrolytically. (2) Condy. meas. have been made of ratios 2:1, 1:1, 1:1.5, 1:2, 1:3, and 1:4 at concn. ranging from 2*N* to 0.005 *N*. (3) Soln. of 2:1 and 1:1 are excellent conductors; 1:2, 1:3 and 1:4 are good conductors in dil. soln. but abnormally low in concd. soln. (4) Hydrolysis into NaOH and colloidal silicic acid is not sufficient to account for this condy. and calcns. have been made of the mobility of the silicate ion. (5) On plotting equiv. condy. against ratio, there is only one change of direction and that a very sharp one at 1:2 in dil. soln.; but in concd. soln. changes of direction also occur at 2:1 and 1:1. (6) It appears likely that salts corresponding to 1:1 and 1:2 exist in soln. and that the other ratios are mixts. of these with NaOH or "hydrated" silica, as the case may be (7) In concd. solns. either the extent of ionization and hydrolysis is very low or aggregate or colloidal formation takes place. E. J. T.

What is humus? S. A. WAKSMAN. *Proc. Nat. Acad. Sci.*, **11,** 463–68 (1925).—Soil organic matter is divided into 3 groups: (*a*) insol. in alkalis, (*b*) sol. in alkalis and pptd. by acids, (*c*) sol. in alk. and not pptd. by acids. The alk. method is to treat 50 gms. of the sample with 100 cc 5% NaOH for 48 hours in the cold. The *a* portion above consists of undecomposed plant residues such as celluloses, and certain synthesized substances like chitin. The *b* portion comprises 60–70% of the org. matter and includes the "humic acids"; it is the most important and interesting portion. It may be divided into two fractions; fraction α which is always pptd. by dil. acids, and fraction β which is pptd. only at a definite isoelectric pt., *p*H 4.8. The α fraction is darker in color, contains more N, and little ash; fraction β is light in color, contains only 1% N, and 30–50% ash, and is responsible for the phenomena usually ascribed to "organic colloids." H. H. S.

Solid hydrogen peroxide; a new analytical reagent. J. R. BOOER. *Jour. Soc. Chem. Ind.*, **44,** 1137 (1925).—Aqueous solns. of H_2O_2 contain free acids, sulphates, phosphates, and alkali metals, and seldom exceed 20 vol. strength or 6% H_2O_2. A compd. which meets the requirements of being neutral, ashless, free from inorg. impurities, and of having as much active O as possible is hyperol, a compd. of H_2O_2 and urea. It has the formula $CO(NH_2)_2$. H_2O_2, and contains 35% H_2O_2. The only impurity is a very small quantity of citric acid, insufficient to affect methyl orange titrations. It is a white cryst. powder which begins to decompose into O, water and urea at 60°C. It will not ignite. H. H. S.

Two new methods of detecting copper. G. SPACU. *Z. Anal. Chem.*, **67,** 31–32 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 831 (1925).—A fluocculent Prussian blue ppt. is produced in neutral Cu solns. by: (1) ammonium thiocyanate and a few drops of 2% alcoholic tolidine, (2) KI and a few drops of 1% alco. benzidine soln. H. H. S.

Gravimetric determination of zinc (and cadmium) by cyanamide. W. MARCKWALD and H. GEBHARDT. *Z. anorg. Chem.*, **147,** 42–49 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 831 (1925). H. H. S.

Sodium silicate solutions. I. Preparation and electrical conductivity. R. W. HARMAN. *J. Physical Chem.*, **29,** 1155–68 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 880 (1925).—The prepn. of solns. contg. Na_2O: SiO_2 in various ratios, starting with the crystalline hydrated metasilicate Na_2SiO_3, $9H_2O$, was affected by electrolytic removal of the alkali. Solns. of ratios 2:1 and 1:1 are excellent conductors; ratios 1:2, 1:3, 1:4 are fair conductors

in dilute soln. but abnormally poor in conc. soln. The results indicate that the salts Na_2O, SiO_2, and Na_2O, $2SiO_2$, exist in soln., and that products with other ratios are mixt. of these with NaOH or "hydrated silica," as the case may be. H. H. S.

Sodium silicofluoride for coagulating rubber latex. H. P. STEVENS. *Rubber Growers Assoc. Bull.*, **7,** 555–60 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 89 (1925).—Sod. silicofluoride is introduced as a powder into the latex. Rubber so produced can be used interchangeably in mfg. with ordinary rubber prepd. by acetic acid. H. H. S.

Measurement of viscosity. J. DUCLAUX and J. ERRERA. *J. Phys. Radium*, **6,** 202–204 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 902 (1925).—A cylinder of porous pot, *e.g.*, a Chamberland filter candle, is substituted for the capillarity of a viscosimeter. H. H. S.

Electrometric titration of fluorides. W. D. TREADWELL and A. KÖHL. *Helv. Chem. Acta*, **8,** 500–507 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 917 (1925).—The soln. contg. fluoride is neutralized, saturated with NaCl, diluted with an equal vol. of ethyl alcohol, and titrated with 0.03N $FeCl_3$ soln. contg. 1% $FeCl_2$, a rapid stream of CO_2 being passed through the soln. to agitate it. The end pt. is detd. graphically from the readings of a millivoltmeter connected to a Pt electrode with a AgCl comparison electrode. H. H. S.

Cristobalite synthesis in the wet way. R. WEIL. *Compt. rend.*, **181,** 423–24 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 918 (1925).—Pptd. SiO_2 was heated for 200 hrs. in a steel tube to 650°–700° in water contg. a small amt. of sodium silicate. Below 650° no cristobalite was formed; above that temp. the product was a mixt. of quartz and cristobalite. H. H. S.

Investigation of "green" clays. G. KEPPELER. *Ber. deut. keram. Ges.*, **3,** 257-70 (1922); *Chimie et industrie*, **12,** 1066–67 (1924).—Allophanoids are characterized by high rate of soln. in HCl and variable ratio of Al_2O_3, SiO_2 and H_2O, whence K concludes they should dissolve by treatment with HCl if they are present. To verify this supposition he examd. Wildstein, Ebernhann and Gross Almerode clays. The amt. dissolved was detd. by heating 10 g. with 100g. of 10% HCl; and 500–1000 g. was heated with 4 times its wt. of 10% HCl and the residue subjected to further tests. The dissolved portion consists largely of Al_2O_3 (and some Fe oxide), most of the SiO_2 of the decomposed silicate remaining undissolved with the clay. This SiO_2 could theoretically be removed by means of NaOH soln., but the latter converts the clay into a sol. and addn. of an electrolyte re-ppts. both SiO_2 and clay. Similar treatment of Zettlitz, Hirschau and Meissen kaolins gave an av. loss of 6% (instead of 10% with the 3 above clays), and a greater proportion of SiO_2 was dissolved. With the kaolins it was possible to complete the treatment with NaOH, and the dissolved mat. was found to consist chiefly of clayey mat. with an Al_2O_3:SiO_2 ratio very near 1 : 2. The HCl treatment causes considerable change in properties, the high colloidal SiO_2 content causing changes clearly shown by increase in hygroscopicity, which is doubled by HCl treatment. The contraction on firing is higher after HCl treatment than before, and NaOH treatment restores the original contraction. With Zettlitz kaolin, progressive addn. of NaOH decreases the amt. of H_2O required for working into paste to a concn. corresponding to 0.30 *N* NaOH, after which the amt. of H_2O increases again. By addn. of humus (0.24%) the amt. of kaolin which can be added can be doubled. Gross Almerode kaolin requires a considerable amt. of H_2O which is practically unaffected by addn. of NaOH or of humus, but is reduced by heating to 200–300°. (*C. A.*)

The formation of eutectic and similar structures in silicate melts. A. F. HALLIMOND. *Trans. Faraday Soc.* **1924** (advanced proof).—The silicate melts should be classified according to the solidification processes. In such a classification the phenocrysts are

most important; next, the binary eutectics. The crystn. sequence is a convenient means of naming the melts, *e.g.*, a fayalite-magnetite-silica slag contains early fayalite, followed by magnetite, and residual silica. The graphic structure, indicating simultaneous crystn. of 2 components, is described in detail. Such structures are best examd. by vertical illumination in polished section. (*C. A.*)

Homogeneous equilibria in magmatic melts and their bearing on the processes of igneous rock formation. PAUL NIGGLI. *Trans. Faraday Soc.* **1924** (advance proof).—The importance of studying the equilibria between mols. of the homogeneous liquid magma phases is emphasized. Magmatic melts contain a great variety of mols., whose mutual equil. depends on external geological conditions of temp. and pressure, as well as on the compn. of the magma. The varying mineral compn. of rocks of the same chem. compn. (*heteromorphism*), and the variability of rock associations are due to this fact. Three predominant types of rock association are described: (1) *Pacific type.* Simple compn.; it contains a min. no. of compds. which suffice to express the compn. of the constituent minerals. It is characterized by extremely simple and uniform equilibria. (2) *Atlantic type.* Complex compn.; with frequent heteromorphism. Desilication is pronounced and may be due to a reaction of the magma with carbonates. Characteristic minerals are sodalite, cancrinite, nephelite, alkali-hornblende. (3) *Mediterranean type.* Intermediate between (1) and (2). (*C. A.*)

The theory of crystallization in rock magmas. C. H. DESCH. *Trans. Faraday Soc.* **1924** (advance proof).—The high degree of mol. association and viscosity in silicate melts is responsible for the difference in their behavior on solidifying from that of metals. The formation of crystals in a rock magma has to proceed in a highly viscous medium, and probably in the undercooled metastable region, in contact with previously formed crystals. This prevents formation of eutectic structures, which might otherwise occur. Investigation of the effects of undercooling, along with the detn. of equilibrium diagrams of binary and ternary systems, provide the best means of studying the theory of crystn. in magmas. (*C. A.*)

Proposed researches on the chemistry and physics of igneous magmas and rocks. J. W. EVANS. *Trans. Faraday Soc.* **1924** (advance proof).—About 34 problems concerning the properties of melts corresponding with igneous rocks, both under uniform and directed pressure, are suggested for invest. The importance of including in such melts sufficient vapor to correspond with that in natural magmas is pointed out. (*C. A.*)

The relation of the physical properties of natural glasses to their chemical composition. W. O. GEORGE. *J. Geology*, **32**, 353–72 (1924).—A table gives a list of 70 glasses and their phys. properties. Fusibility, color, hardness, soly. and magnetism were found to give unreliable indications of the nature of the glass. The *ns.* and sp. grs. are closely related to compn. and hence very useful in detg. the character of the glass. The SiO_2 content of the glasses varied from 40 to 82%; sp. gr. = 2.02 to 2.903; $n = 1.48$ to 1.62. (*C. A.*)

The analysis of boron minerals. Methods for borate of lime. R. PORTER. *Chem. Trade J.*, **75**, 616–17 (1924).—Common borate of lime is approx. $Na_2B_2O_4.CaB_6O_{10}.15H_2O$ but is likely to contain $CaSO_4$, NaCl and other impurities. *Insoluble matter.* Dissolve 5 g. of sample in 70 cc. of 1.8 *N* HCl, heating 20 mins. Filter, ignite and weigh. *Iron and alumina.* Make up the filtrate to 500 cc. and ppt. Fe and Al with NH_3 in 100 cc. of aliquot. Ignite and weigh as Fe_2O_3 and Al_2O_3. *Lime.* In the filtrate from Fe and Al, det. Ca in the usual way by CaC_2O_4 pptn. *Magnesia.* Det. as $Mg_2P_2O_7$ in filtrate from Ca. *Sulphates.* In another aliquot of 100 cc. det. as $BaSO_4$ in the usual way. *NaCl.* Dissolve 5 g. of fresh sample in 50 cc. of water, add an excess of $CaCO_3$ and a little K_2CrO_4 soln. Titrate Cl by Mohr's method. *Water and org. mater.* Ignite 5 g. of sample and call the loss water and org. matter. *CO_2.* For this detn. Shrötter's alkalimeter is

recommended. *Boric acid.* Treat 5 g. of sample with 70 cc. of dil. HCl and boil 20 mins. Cool, neutralize with $NaHCO_3$ and filter into a 500-cc. measuring flask. Take 0.2 of the filtrate, make acid and expel all CO_2. Neutralize with NaOH, add glycerol and titrate. (*C. A.*)

The crystalline modifications of $NaAlSiO_4$. N. L. BOWEN and J. W. GREIG. *Am. J. Sci.*, **10**, 204–12 (1925).—Two cryst. modifications of $NaAlSiO_4$ have been recognized, the hexagonal form, nephelite, stable below 1248°; and an intricately twinned form, carnegieite (soda anorthite), stable above 1248°. The form which is stable above 1248° is found to be isometric, and assumes the intricately twinned, birefringent state as a result of a low-temp. inversion. Thermal effects were measured by the method of the differential thermocouple. The low-temp. inversion occurs at 690° corresponding to an abrupt appearance or disappearance of birefringence. In one of the prepns. investigated, still another inversion took place at 226.5° with an abrupt increase of birefringence on heating and a very gradual fading out of birefringence on cooling. The upper inversion occurred at 655° for this prepn. (*C. A.*)

Adsorption. A. V. SLATER. *Chemistry and Industry*, **44**, 161–64 (1925).—A brief review of the current ideas on adsorption. Adsorption is defined as the concn. of 1 substance at the surface sepg. it from another, providing a layer of increased concn. only a few mols. thick at the most. The subject is treated under the headings: the kinetics of adsorption, surface forces, specific nature of adsorption. (*C. A.*)

BOOKS

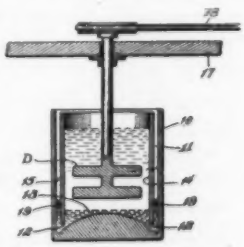
Das Wasserglas. H. MAYER. Braunschweig; F. Vieweg u. Sohn A-G., 1925. Describes the properties, manuf. and uses of sodium silicate. H. H. S.

Electrical precipitation. O. LODGE. London: Oxford Univ. Press, 1925. H. H. S.

PATENTS

Zirconium-oxide complex and method of producing and using the same. CHARLES J. KINZIE. U. S. 1,562,890, Nov. 24, 1925. The method of treating mat. composed preponderatingly of zirconia, but containing also undesired impurities which comprises mixing said material with a relatively small quantity of independently thereof co-vitrifiable ingredients, and heating the resulting charge until said impurities shall have been decomposed and eliminated therefrom.

Process for the production of potassium carbonate. HEINRICH KLOPSTOCK AND WALTHER NEUMANN. U. S. 1,562,891, Nov. 24, 1925. Process for the production of potassium carbonate of a desired degree of purity by treating a caustic potash solution of suitable strength with carbonic acid, according to which the carbonic acid treatment is incomplete so that a proportion of caustic potash, which is greater or less according to the degree of purity desired in the product, remains in soln. in the mother-liquor, whereby impurities are to a certain extent retained, and the potassium carbonate is then separated in any suitable manner.



Production of silicic acid. NEWELL L. COLLINS. U. S. 1,562,940, Nov. 24, 1925. A process of producing pure silicic acid consisting in electrolyzing an aqueous soln. of water glass between an anode and a mercury cathode and continuously agitating the anode.

Process for producing artificial cryolite free from iron, from aluminum-salt solutions containing iron. HEINRICH SPECKETER. U. S. 1,563,536, Dec. 1, 1925. A process of producing artificial cryolite free from iron from aluminum salt solns. containing iron, which process comprises adding to the said solns. while stirring 9 molecules of hydrofluoric acid at most and 3 molecules of alkali metal chloride

at least to one molecule of aluminum oxide and treating in the presence of water the ppt. thus obtained with alkali metal fluoride.

Process of producing ferro-zirconium. RALPH H. MCKEE. U. S. 1,565,280, Dec. 15, 1925. The process of producing zirconium alloy which consists in fusing an oxygen compd. of zirconium with a metallic sulphide.

Synthetically-made precious stone and method of producing the same. DAVID BERTOLINI. U. S. 1,565,777, Dec. 15, 1925. A synthetic stone having the hardness of a natural sapphire and the color and appearance of a natural aquamarine composed of alumina, and oxides of magnesium, cobalt and vanadium in the proportion of approx. 86% of alumina, 14% of oxide of magnesium and a trace of oxide of cobalt and oxide of vanadium.

General

Statement on behalf of education committee. W. K. MCAFEE. *Bull. Amer. Ceram. Soc.*, **5** [1], 6–7 (1926).—M. presents questions regarding the specialization in a four-year course in ceramic engineering and the possible need for preliminary training in secondary schools to help the student choose the branch of the industry he intends to follow more intelligently. There is also brought out for discussion the idea of having the courses to teach the graduate engineer to think of the quality of the finished product more than just the lowering of costs. E. J. V.

Ceramic education as applied to the refractories industry. M. C. BOOZE. *Bull. Amer. Ceram. Soc.*, **5** [1], 19–20 (1926).—B. shows the weakness of the four-year course in trying to cover the whole field of ceramics. Either extending the course or requiring specialization for one branch of the industry is suggested. Reasons for this sugestion are brought forth by particular reference to the refrac. industry and its many complexities. E. J. V.

Ceramic art and the ceramic artist. EDMUND DE F. CURTIS. *Bull. Amer. Ceram. Soc.*, **5** [1], 42–45 (1926).—The great gulf between art and industry in ceramics is due to the lack of provision in undergraduate work for proper artistic training. C. thinks that in order to raise the standard of American ceramic art to its justly expected heights, the ceramic artist must be brought into being. His training must be such as to make him a practical craftsman as well as an artist. E. J. V.

Should product and product requirements be stressed more in school curricula? AMOS P. POTTS. *Bull. Amer. Ceram. Soc.*, **5** [1], 24–27 (1926).—The popular answer to this question is in the affirmative but P., basing his statements on an anal. of the various curricula, shows the practical impossibility of so doing during undergraduate courses. Conditions in a graduate school are such that it is much more practical to stress product and product requirements there. E. J. V.

Extension work in ceramic engineering. A. S. WATTS. *Bull. Amer. Ceram. Soc.*, **5** [1], 20–24 (1926).—The more complete organization of the country for engineering extension service similar to that for agriculture is urged. A general history of the development of the existing extension service is given. W. recommends the creation of a committee of representatives of every type of ceramic industry to consider the most needed form of ceramic extension service and the methods to be employed in securing the same. E. J. V.

Opinions of a factory man on ceramic education. CHAS. W. HILL. *Bull. Amer. Ceram. Soc.*, **5** [1], 7–18 (1926).—Suggestions by factory men regarding training along certain lines of ceramics may be beneficial to both the industries and the colleges but their application must be worked out at each school according to local conditions. Many practical limitations prove obstacles to educational advancement in technical lines. The five general types of work employing men trained in ceramics, *viz.*, research,

factory lab., tech. control, factory management and sales, are discussed, pointing out out opportunities for ceramic colleges to place emphasis on special phases of work suitable for each. A summary of six of the leading courses in ceramics is given and the various individual courses offered are discussed, with suggestions as to possible improvements. A more careful anal. of the subject matter and time devoted to purely ceramic subjects was found impracticable from the available information. The stressing of the properties of indus. products is impossible in colleges due to the frequent changes made necessary by the changes in the detg. factors, such as equipment and processes of manuf. In general, the study of the relationship between properties and service involves other branches of science and calls for highly trained specialists in those lines. A student of ceramics could obtain a thorough knowledge of the relations for one specific product through specialization but might then be so unfortunate as to secure employment in an altogether different branch of the industry where he might never use his information. This is contrary to the best principles of college education, which are to give the student a fund. background of science, mathematics and ceramics, to teach him orderly methods of thought and experimentation and to give him confidence in himself. More emphasis should be placed on methods of detg. physical properties of ceramic products and on the relation of compn. and treatment to the physical properties. Ceramics is still in an empirical stage and needs the development of more general laws and formula similar to those in physics, chemistry and mechanics. "Practical dope" given out by some teachers is a deadly drug. Students must be made to be self-reliant and to go back to funds. on all problems. Manufacturers should realize what may be reasonably expected from young graduates. Much can be done to improve ceramic education by a greater coöperation of the practical and theoretical men and the removal of many restrictions now in vogue. E. J. V.

American ceramic art symposium. F. K. PENCE. *Bull. Amer. Ceram. Soc.*, **5** [1], 27–42 (1926).—A symposium led by P. The question of American china ware vs. European ware is discussed as to beauty and utilitarian value by (1) a whiteware manufacturer, (2) a decorator, (3) a producer of a distinctive line of vases, (4) a mfg. ceramic sculptor, (5) a mfg. art potter, (6) an editor, (7) a porcelain manufacturer, (8) a pres. of a whiteware company, (9) a supt. of a large factory, (10) a mfg. manager, (11) a manager of an art ware pottery and (12) a ceram. material importer.

American ceramic art for America. M. T. WEAVER. *Bull. Amer. Ceram. Soc.*, **5** [1], 45-47 (1926).—A suggested course to prepare artist-potters for work upon ceramic art problems is suggested by a teacher in the Cleveland School of Art.

Discussion on "Electric furnace for softening point determinations," G. ROSS. *Bull. Amer. Ceram. Soc.*, **5** [1], 47–48 (1926).—A brief discussion on a paper by W. L. PENDERGAST published in *Jour. Amer. Ceram. Soc.*, **8** [5], 319–25 (1925).

The mineral resources of northern Ontario. W. A. PARKS. *Jour. Roy. Soc. Arts*, **73,** 3796, 898-917 (1925).—This paper is directed principally to the occurrence of metals and metal bearing ores in Ontario, Canada, and the geological formations in the province, Gypsum in thick beds of great purity occurs for miles along the Missinaibie River and streams in the east. E. J. T.

Types of electric heating appliances for industrial use. R. M. KEENEY. *Chem. Met. Eng.*, **32,** 855-59 (1925).—Discusses space heaters, plate heaters, cartridge heaters, oven heaters and immersion heaters, with the principal application of each type. Points to be considered in the purchase of elec. equipment are the line voltage available, the alloy used in the resistor, the temp. to be obtained, the insulation of an oven, and the distribution of heating units within the oven, and the method of supporting the resistors. M. E. M.

The rôle of mental measurement in the discovery and motivation of the gifted student. C. E. SEASHORE. *Proc. Nat. Acad. Sci.*, **11**, 542-45 (1925). H. H. S.

The distribution of correlation ratios calculated from random data. H. HOTELLING. *Proc. Nat. Acad. Sci.*, **11**, 657-62 (1925).—A study of the problem: What is the probability of obtaining an apparent correlation between data when no true correlation exists? Allusion is made also to errors of "sampling" disguising true correlation. H. H. S.

Exchange of government workers. ANON. *Jour. Soc. Chem. Ind.*, **44**, 1076 (1925).—Under the scheme whereby the U. S. and British Govts. exchange scientists, Dr. R. Thiessen, an authority on U. S. coal, has taken up duties at Sheffield Univ. H. H. S.

Report of the Committee of the Privy Council for scientific and industrial research for year 1924-25. ANON. *Jour. Soc. Chem. Ind.*, **44**, 1125–26 (1925).—Under the Building Research Board, the chem. work has related to cements high in alumina, non-corrosive oxychloride, the general prob. of the preservation of bldg. stone, the structures and strengths of mats., and the fund. constn. of bldg. mats. which show change in vol. owing to the action of moisture. Other committees have supervised work on optical glass, color meas., concrete, spectrographic anal., phys. constants at high temps., elasticity of mats., and many other subjects. The work on the production of pure metals has led to a magnesia crucible which resists the action of iron oxide. Grants to 21 research assocns. totalled £100,118, and to 258 research workers and students £35,000. H. H. S.

Clay purification. Sulphite liquor as a protective colloid. E. C. BINGHAM, G. F. ROLLAND, and G. E. HILBERT. *Ind. Eng. Chem.*, **17**, 952-53 (1925); *Jour. Soc. Chem. Ind.*, **44B**, 800 (1925).—Sulphite collulose waste liquor after purification possesses remarkable wetting power, and its use is suggested for purifying mats. like clay, bentonite, and graphite, and in cases where the amt. of vehicle is required to be kept low; and as a deflocculating medium in making up ware from clay. To overcome the volatility of the water in the liquor, a little glycerine may be added. H. H. S.

Ohio ceramists meet. ANON. *Pottery, Glass and Brass Salesman*. **32** [18], 11 (1925).—An account of the second annual meeting of the Ohio Ceramic Industries Assn. Papers presented were: "The Ceramic School at East Liverpool," by KENNETH SMITH; "Ceramic Extension Service for Ohio," by A. S. WATTS; "The Organization of Agricultural Research through Federal and State Agencies," by G. W. MCCUEN; "The Coöperative Policies of the State Board of Vocational Education," by E. S. HEUSCH; "The Reorganization of Ceramic Research under the Federal Government and What It Means to the Ohio Industries," by R. C. PURDY; "The Necessity for Organized Plans by the Ceramic Industry before the State Can Provide Coöperative Aid," by E. H. HITCHCOCK. F. G. J.

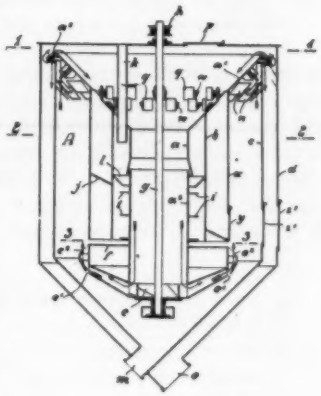
Important investigations under way by Mines Branch. ANON. *Can. Chem. Met.*, **9** [10], 226 (1925).—Under ceram. are listed a general invest. of the condition of the ceram. industry in various parts of the country and a study of the clay and shale resources of Manitoulin Island. Considerable time was spent on the invest. of special probs. in the manuf. of brick and tile to devise ways of lowering cost and improving quality. Lab. invests. will include routine testing of mats. and products and in pottery production and in the compounding of special porcelain bodies with a view to developing certain waste products from Can. mines. Expts. will be made on Can. magnesite for refrac. purposes. A study will be made in respect to the formulation of methods for detg. refractoriness of molding sands in collaboration with the U. S. Bur. of Mines. F. G. J.

Ceramic extension education at Iowa State College. PAUL E. COX. *Clay Worker*, **84** [2], 134 (1925).—Paper read at the Summer Meeting, AMERICAN CERAMIC SOCIETY, July, 1925. F. G. J.

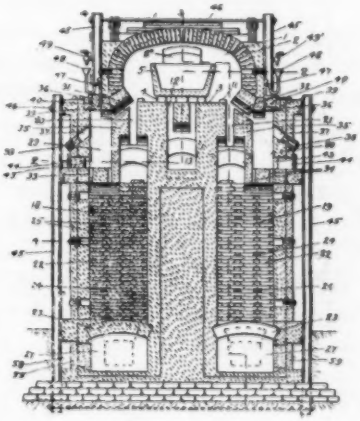
Kiln stokers. JOHN D. MARTIN. *Clay Worker*, **84** [2], 110 (1925).—Paper presented at AMERICAN CERAMIC SOCIETY Annual Meeting, Feb., 1925. (See *Jour. Amer. Ceram. Soc.*, **8** [6], 396–400 (1925). F. G. J.

PATENTS

Apparatus for sifting fine material. GEORG ROTH. U. S. 1,565,236, Dec. 8, 1925. An app. for separating fine mat. comprising in combination a cylindrical casing, a plurality of walls being arranged concentrically to said casing and suitably connected to each other, a suction pipe attached to a central driving axle and arranged in line with the shortened inner wall and having a disk shaped lower end, a centrifugal blower fixed to the lower end of the central axle near the lower opening of said suction pipe, a rotatable member mounted on the lower end of said suction pipe and so fitted with a horizontal surface that the mat. which is supplied to said member will be discharged centrifugally from said member when the same rotates, a conical plate connected to the bottom of said blower and being upwardly bent against said dish-shaped pipe so as to form a ring-shaped outlet for the distributing air current being produced by said blower, and means for generating an auxiliary horizontal air current adapted to act upon the falling mats. and to regain the finer particles from the coarse mat. falling to the outlet, and means for separating the fine particles from the air currents resucked by said blower, substantially as set forth.



Furnace. NICHOLAS I. IVANOVSKY. U. S. 1,565,370, Dec. 15, 1925. In a fur., the combination with a combustion chamber, a regenerative chamber adjacent to said combustion chamber, a plurality of brick walls forming passages in said regenerative chamber means to heat said walls by the exhaust gases from said combustion chamber, a gas producing chamber made of refrac. material adjacent to said regenerative chamber and to said combustion chamber, the walls of said gas producing chamber being provided with apertures communicating with said regenerative chamber and with said combustion chamber, means to heat the walls of said gas producing chamber by means of the exhaust gases from said combustion chamber, means to admit fuel into said gas producing chamber, and means to admit air into said combustion chamber partly through said regenerative chamber and partly through said gas producing chamber.



BOOK REVIEW

The 1925 Edition of Tentative Standards of the American Society of Testing Materials.

This volume comprises 876 pages and contains 194 "Tentative" standards as follows: 24 relating to steel ferro alloys and wrought iron; 17, non-ferrous metals; 20, cement, lime, gypsum and clay products; 16, preservative coatings; 21, petroleum products and lubricants; 45, road materials; 3, coal and coke; 5, timber; 9, water proofing; 8, insulating materials; 4, shipping containers; 3, rubber products; 8, textile materials; 2, slate; 9, miscellaneous. The standards are "tentative" and are published with a view to eliciting suggestions and constructive criticisms, of which the respective committees will take cognizance before final adoption of the standards.

Following is a list which will be of particular interest to the ceramic profession:

Specifications and Tests for Portland Cement, for natural cement, for paving brick, for building brick, for clay sewer pipe, for clay sewer brick, for cement-concrete sewer pipe, for drain tile, for hydrated lime for structural purposes, for quicklime and hydrated lime for use in cooking of rags for the manufacture of paper, for quicklime and hydrated lime for use in the textile industry, for quicklime and hydrated lime for the manufacture of silica brick, for gypsum, for calcined gypsum, for gypsum plasters, for gypsum plastering sand, for gypsum wall board, for gypsum plaster board, for gypsum partition tile or brick, and for fire tests of materials and construction.

Standard Methods

Of tests for refractory materials under lead at high temperatures.
Of test for porosity and volume changes in refractory materials.
Of test for the softening point of fireclay brick.
Of ultimate chemical analysis of refractory materials, including chromes and chrome brick.
Of testing molded insulation.

Standard Definitions

Of terms relating to sewer pipe.
For clays refractories.
Of terms relating to hollow tile.

Recommended Practice

For laying sewer pipe.

This volume can be obtained from the American Society of Testing Materials, 1315 Spruce Street, Philadelphia, Pa. The price is $7.00 in paper, and $8.00 in cloth binding.

R. M. KING.

BULLETIN

of the

AMERICAN CERAMIC SOCIETY

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

Mary G. Sheerer, H. Clinton Baldwin, M. E. Manson, H. G. Wolfram	Art, Enamel	A. Silverman, A. N. Finn, C. E. Bales, L. C. Hewitt, F. H. Riddle, F. H. Rhead	Glass, Refractories, White Ware	E. C. Hill, G. M. Tucker, J. D. Martin, A. P. Potts	Terra Cotta, Heavy Clay Products

OFFICERS OF THE SOCIETY

E. Ward Tillotson, President
Mellon Institute, Pittsburgh, Pa.
F. H. Rhead, Vice-President
American Encaustic Tiling Co., Zanesville, Ohio
H. B. Henderson, Treasurer
Standard Pyrometric Cone Co.
1538 N. High St., Columbus, Ohio
Ross C. Purdy, General Secretary
Helen Rowland Fox, Assistant Secretary
Emily C. Van Schoick, Assistant Editor
Lord Hall, O. S. U., Columbus, Ohio

TRUSTEES

R. D. Landrum
A. F. Greaves-Walker
R. R. Danielson
J. C. Hostetter
C. Forrest Tefft
J. S. McDowell
R. L. Clare
C. C. Treischel
Paul E. Cox

Vol. 5 February, 1926 No. 2

EDITORIAL

FORWARD STEPS IN CERAMIC EDUCATION

Many forward going ways and means in ceramic education have been developed during these thirty-one years of formal collegiate ceramic instruction. Nine universities in the States and two in Canada have laboratory and lecture courses in ceramic science and engineering and three universities have well-established combination courses in ceramic art and science. The University of Pittsburgh has announced an institute of glass technology. Massachusetts Institute of Technology, Stanford University, of California and University of Louisiana have plans well-developed for opening ceramic courses in ceramic science and engineering this fall. Rolla School of Mines has plans matured with support of Missouri ceramists for presenting to the legislature a bill authorizing a ceramic department.[1] Syracuse and other universities are opening ceramic art courses. The Lincoln High School in Los Angeles has an $80,000 ceramic building under construction to care for its rapidly growing ceramic department and East Liverpool High School has equipped laboratories and last fall began classes in ceramic lectures

[1] See *This Bull.* p. 168.

and laboratory. There are several high schools, like Schenley in Pittsburgh and Central in Wheeling, which have highly developed ceramic art and ceramic science, technology and art. There are local art schools like Trenton and there are several clubs which have progressed in ceramic art and in the technology which applies. High schools everywhere have some sort of ceramic work in their art craft departments as seeds planted which if the environments permit will become full-fledged ceramic departments. The volume of requests for high school instructors competent to teach the ceramic fundamentals in combination with the arts and crafts of ceramic ware production indicates that with qualified instructors ceramic courses in high schools would soon be instituted quite generally. Inquiries for summer courses of training in ceramic technology, arts and crafts are frequent and Chautauqua organizations are surveying the desirability of training courses in ceramics.

Secondary ceramic schools will be feeders directly to the industries of boys and girls who cannot go to college. They will also feed directly into the collegiate ceramic departments with those pupils who have an aptness for greater accomplishments in ceramics by further training in mechanical processing and product designing. It appears on first thought (and it endures through careful study of the situation) that American ceramics will be greatly advanced in every respect when high schools generally have adequately equipped and qualified instructional leadership in ceramic technology, art and craftsmanship.

University extension by correspondence and winter short courses have proved their value. Itinerant lecturing and demonstrating is becoming popular. Proving the application in operating plants of the fundamentals and general principles is a natural outcome of joint investigations by industrial firms and universities. Scheduled foremen institutes in industrial centers will be organized when the universities will be able to provide the instructors. These means of making educational opportunities available to plant operators will be provided only in response to demands by the industrial managers and unless they are misjudged, these managers are anxious to make demands for and will support university extension when they find how they can proceed.

This sketchy survey of the present status and trend in facilities for ceramic education is a bare statement of facts. Either justification or criticism of these developments would be idle. Ceramic schools will increase in number and variety in response to the apparent if not real industrial demand for better trained ceramic workers.

The greatest concern in this educational development is competent, inspiring instructors. The value and effectiveness of these schools depends altogether on their instructional directors. The best equipped

schools with poorly trained instructors will not be as successful in training youths as will poorly equipped schools directed by competent instructors. Qualified instructors are more important than any material equipment. The task of most immediate need is providing these schools with competent instructors.

These several ceramic schools have multiplied at such a rate and in such numbers as to have exhausted the supply of adequately trained instructors. They have given rise to the very serious economic problem of how, through competent direction, to use their equipment most profitably.

These several schools represent a large financial investment and the potential value of their service to the ceramic industries is beyond one's ability to estimate. It is economically important that the schools secure through the education committees of this SOCIETY and of every other ceramic organization a coördinated effort (1) to have men and women with aptness in teaching take post graduate work in the collegiate ceramic schools, (2) to establish combination ceramic science and art courses, and (3) to plan for a combination industrial and scholastic training in preparation for teaching ceramics in these schools. It seems to be a wastage of money and effort to multiply ceramic schools without making provision for the training of instructors to competently direct them.

PAPERS AND DISCUSSIONS

MONOGRAPH AND BIBLIOGRAPHY ON TERRA COTTA[1]

By Hewitt Wilson

Abstract

A. Introduction
- I. Beginnings and progress.
- II. Advantages.
- III. Location of plants.
- IV. Development of terra cotta surfaces.
- V. Classification.

B. Terra Cotta Body
- I. Body requisites.
- II. Body mixture.
  1. Terra cotta clays.
  2. Grog and non-plastics.
  3. Soluble salts and the addition of barium compounds.
- III. Methods of mining, handling and mixing clays.
  1. Green spots.
- IV. Tempering methods.
- V. Aging.

C. Drafting and Plaster Work
- I. Drafting.
- II. Modeling and mold making.
  1. Ashlars.
  2. Profiles.
  3. Old molds.
  4. Checking the ware through the shop.

D. Pressing and Finishing
- I. Pressing.
  1. Power methods.
  2. Hand pressing.
  3. Absorption of water by mold.
- II. Finishing.
  1. With steel.
  2. With water brush.

E. Drying
- I. Preliminary drying.
- II. Final drying.
  1. Humidity drying.

F. Slips, Glazes and Spraying
- I. Storage, mixing and identification of raw materials.
- II. Preparation of slips and glazes.
  1. Specific gravity control.
  2. Viscosity control.
- III. Spraying.
  1. Handling ware during spraying.
  2. Spraying technique.
- IV Underslips.
- V. Glazes.
  1. High temperature. Gloss and mats.
  2. Low temperature.
  3. Glaze fit and defects. Staley's coefficient of expansion factors.
- VI. Vitrified slips.

G. Color Work
- I. Common colors.
  1. White.
  2. Cream.
  3. Gray.
  4. Tan and brown.
- II. Polychrome colors.
  1. Blue.
  2. Green.
  3. Pink.
  4. Black.
  5. Low heat overglaze.
- III. Granite Finishes.
- IV. Pulsichrome applications.

---

[1] This is a companion publication to a series of abstracts covering the manufacture of terra cotta mimeographed by the ceramic engineering department, Univ. of Wash., Seattle, in 1923, in coöperation with the Northwest Station, U. S. Bur. of Mines.

V. Polychrome decoration.
1. Painting.
2. Spraying with masks.
3. High temperature overglaze.
4. Painting soluble metallic salts.

H. Kilns and Firing

I. Kiln construction.
1. Flue arrangement.
2. Fire boxes.
II. Setting.
III. Firing.
IV. Cooling and dunting.
V. Composition and dunting.
VI. Pacific Northwest Clayworkers' Kiln Data.

I. Fitting Department

J. Terra Cotta in the Wall

I. Elasticity.
II. Thermal coefficient of expansion.
III. Thermal conductivity.
IV. Porosity and absorption.
V. Crystallization of water and salts.
VI. Strength of body.
VII. Variations of strength when wet and dry.
VIII. Concentration of loads.
IX. Jointing.
X. Concrete.

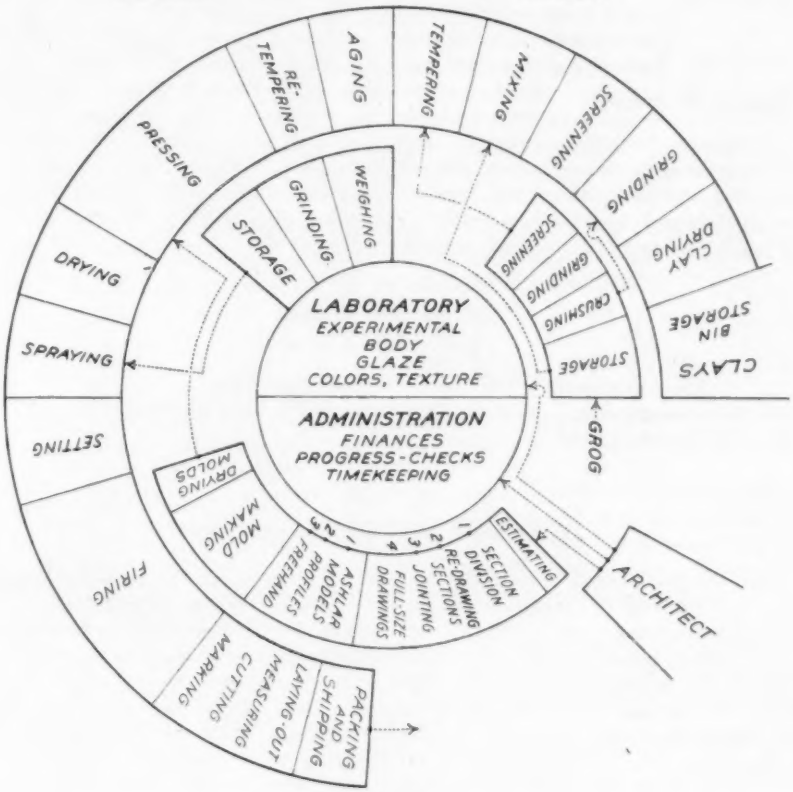


FIG. 1.

A. Introduction

I. Use of Terra Cotta

"The use of fired clay ware in the form of brick, tile or pottery has been uninterrupted and universal from the dawn of civilization to the present day. The use of fired clay

ware in the form of architectural terra cotta has been more sporadic and local. Its unequalled merits as a building material were fully appreciated by the Greeks and Tuscans who, two thousand years ago, used it to face the perishable stone in some of their temples. Centuries passed, during which the art of making architectural terra cotta seemed to have been confined to short periods and a few localities. In modern times, the creator of the skyscraper, the progressive American architect, working with the responsive and enterprising manufacturer, rediscovered, improved and gave to an appreciative public this most durable and versatile of all building materials."[1]

II. Advantages

1. General use Terra cotta can be used on any size of a building from the one-story store front to the Woolworth building. Its lightness is necessary for the latter type of construction.

2. Cleanliness The vitreous and glazed surface can be washed each year with soap and water and the building will be as clean and fresh as when new. This is an advantage in the large and dirty cities where cleanliness is desirable.

3. Durability Terra cotta is fire-proof and water-proof, permanently enduring.

4. Ornamental features Brick and machine made facing material offer but a limited field for an architect's decorative ideas. Ornamental features of cut stone are costly. Any design, ornamental feature, surface finish can be produced on the terra cotta face. Polychrome or different colored designs are now widely used by architects who formerly have been limited to the natural colors of stone or the simple fired colors of brick. Terra cotta colors now rival those of painted surfaces in the quality of color and execution of design.

III. Location of Plants

	Plants		Plants
1. East Coast group	11	4. Pacific So thwest	4
2. Chicago group	4	5. Pacific Northwest (Wash.)	4
3. Western group	4		
		Total	27

IV. Development of Terra Cotta Surfaces

Since the beginning of terra cotta work in this country in 1853, surface coatings, colors and methods of application have been changing and developing to suit the progress and varying tastes of modern architectural development. While the molding and body ornamental work has varied somewhat, the greatest changes have been made in the exterior protective coatings. The latter were not used with the earliest terra cotta but the practice was widely adopted about 1884. The first coatings were the vitrified slips made of simple clay mixtures of red, buff and gray colors. White vitrified slips were developed later and full glazes were not introduced commercially until 1897. Matt glazes, polychrome and granite decorations are of comparatively recent origin while one of the most recent developments is the pulsichrome series of colors in both glaze and vitrified slip textures. In the beginning, terra cotta was largely used to imitate the

[1] Architectural Terra Cotta, Standard Construction. National Terra Cotta Association 1914.

natural building stones such as granite and sandstone, but it now has progressed to an independent stage and can no longer be considered as an imitation of other structural materials.

Notwithstanding the fact that terra cotta has put on fastidious, up-to-date and highly colored decorations, the present body underneath the coating is very similar to those of earlier dates. In fact, because cone 8 was a common cone-temperature for firing terra cotta, some of the older, and it is true, darker colored bodies have shown better weathering qualities than many of recent production.

V. Classification

At the present time we can divide the terra cotta of this country into three general over-lapping classes: High, medium and low-fired ware, heated respectively to cones 6-7, cones 3-5 and below cone 3, usually in the neighborhood of cones 01 to 3.

Classified according to the character of the exterior coating, we have two general classes: (1) Vitrified and (2) Glaze coatings.

1. Vitrified Coatings The original vitrified coatings were composed of the natural clays and were usually buff, brown or red in color. These clays, blended with more or less fluxing material, are still used to a considerable extent for producing the darker and colored vitrified coatings. When light gray or cream were wanted it was necessary to use veneerings, similar in composition to the porcelain or earthenware bodies. These are produced with mixtures of feldspar or Cornwall stone, ball clay, kaolin and flint as the basic materials with the addition of fluxes or frits for the lower temperatures.

2. Glaze Coatings The Bristol type of glaze, long used in the stoneware industry, with its later additions of barium, magnesium and tin oxides serves for firings above cone 4 while fritted glazes are used below that heat.

B. Terra Cotta Body

I. Requisites of a Terra Cotta Body

1. Excellent plastic working properties to permit the pressing of intricate shapes and large pieces. A minimum plastic tensile strength of 2.0 pounds per square inch.
2. A maximum of 5.0% drying shrinkage.
3. Sufficient dry strength to enable the large pieces to be handled without breaking or rubbing off. The dry transverse strength should be near 350 pounds per square inch.
4. A piece of terra cotta, approximately 1 ft. 6 in. × 1 ft. × 6 in. should dry without cracking or warping in 30 hours in the common steam drier. This can be reduced to 18 hours in a humidity drier. Larger pieces will take a longer time.
5. The total shrinkage should not be over 1 inch per foot.
6. Good strength must be developed by cone 6. The crushing strengths of terra cotta ware range from near 3500 to 13,500 pounds per square inch with an average near 8,000 pounds. The fired transverse strength will average about 2,000 pounds per square inch with a range of 1500 to 3000 pounds.
7. Absorption range is from near 8.00 to 22.0%. Average near 14.3%.
8. The fired color must be buff, light gray or light brown.

II. The Terra Cotta Body Mixture

1. Terra Cotta Clays Clays having widely different properties are blended to produce bodies or mixtures having common characteristics. Most of the clays used are either of the buff firing stoneware or low grade fireclay type. They

should have a good bonding power and good plastic working properties. They should not contain pebbles, pyrites or similar objectionable materials and the soluble salt content should be low. The clays should run uniform in the bed. Large quantities are prepared ahead and several clays are used together to secure this uniformity. Otherwise the shrinkage is not reliable. The clays should not produce warping and cracking in drying and firing. A good firing strength should be produced at least by cone 6. The clays should be light firing; buff, light gray or brown. Small amounts of red firing clays are sometimes used to reduce the firing temperature. The total fired shrinkage of the individual clays will run from 7 to 14% depending on the sandiness and nature of the clay. Very plastic, high shrinkage clays are offset with sandy clays or high grog contents.

2. Grog and Non-plastics From 20 to 45% grog is blended with one or more clays which have varying degrees of bonding power and are more or less sandy. If the clay mixture is plastic with high shrinkage, higher quantities of grog are used; if the clays are sandy, lower quantities of grog are added. Reasons for using grog: Reduction of shrinkage, prevention of warping, production of straight edges and accurate dimensions. The use of grog is similar to calcining or fritting portions of other types of bodies and glazes. The water content is reduced and carbonaceous and other volatile matter is removed.

TABLE I
MECHANICAL ANALYSES OF COMMERCIAL GROGS

	No. 1	No. 2	No. 3	No. 4
Plus 20-mesh	2.7	48.4	11.9	3.6
20 to 40	18.2	17.3	36.0	33.4
40 to 100	36.0	17.8	23.4	29.3
100 to 200	15.3	5.9	10.3	15.0
Minus 200	27.8	10.6	18.4	18.7
	100.0	100.0	100.0	100.0

a) Composition of Grog Scrap terra cotta, fire brick, saggers, scrap pottery, sanitary ware, hollow tile or specially calcined terra cotta clays. With the same grinding facilities a harder grog will give a coarser ground mixture if screened on the same sieve. For example, compare grog analyses (3) and (4). Number 3 contains 10% terra cotta scrap, 10% fire brick scrap and 80% pottery saggers. Number 4 contains 60% terra cotta scrap and 40% pottery saggers. The saggers are much harder to grind than the terra cotta or fire brick. Consequently Number 4 grog was pulverized to the finer sizes while a larger percentage of No. 3 just passed the 18-mesh screen. Also wet grog grinds more easily than dry. Vitrified grog is very hard on the grinding machinery but produces excellent grog. Blast furnace grog with its low cost in some districts and light weight has been proposed by Minton.[1]

METHOD OF DETERMINING THE NON-PLASTIC CONTENT OF A TERRA COTTA BODY

1. Blunge a 500-gram sample in a small churn or soak over night and blunge by hand.
2. Analyze by screening.
3. Collect washings in a bucket and after stirring allow the slip to settle for one minute. Decant, wash and resettle.
4. Repeat the process until the water is clear.
5. Dry residues and weigh.

[1] *Jour. Amer. Ceram. Soc.*, **1**, 185 (1918).

This method will catch the non-plastic fine sand and grog which passes the finest screens. If the shale type of clays are used, the shale particles will be caught in the non-plastic portion. These act as grog during drying, but shrink during firing. Examples of non-plastic analyses:

TABLE II

	No. 1	No. 2	No. 3	No. 4	No. 5
Plus 20-mesh	8.7	5.0	2.4	4.3	5.7
20 to 40	9.4	12.6	8.2	12.7	11.2
40 to 100	7.4	12.7	20.0	9.5	9.4
100 to 200	5.4	6.1	9.6	6.0	7.1
Subsidence residue	13.1	7.4	10.1	7.5	6.6
Total non-plastic	44.0	43.8	50.3	40.0	40.0
Approx. clay content	56.0	56.2	49.7	60.0	60.0
Total	100.0	100.0	100.0	100.0	100.0
Per cent grog added	30	33⅓	20	40	40
Type clays	Sandy	Sandy	Very Sandy	No Sand	No Sand

3. Soluble Salts and the Addition of Barium Compounds

The slightly soluble sulphates of calcium and magnesium cause trouble in the manufacture of terra cotta; not from unsightly efflorescence on the finished ware as on brick work but because these salts prevent adhesion of the underslips and glazes to the body. An irregular coating of salt scum is formed on the surface of the terra cotta during drying, particularly on the edges and corners from which the greatest evaporation takes place. These accumulations are irregular and apparently vary with a variable soluble salt content in the different clays or grog.

One would think that the water received from two coatings of underslip and two more of glaze would be sufficient to redissolve these salts and carry them to the outer surface of the glaze where their separation effect would be lost. However, it appears that both the time and water are limited for the solution of these difficult soluble materials and they remain to form a plane of separation between the body and the underslip. If the glazed surface, particularly along the edges, is tapped with a coin or small chisel after firing, flakes of underslip with adhering glaze will fly off. In severe cases the glaze and underslip will be found lifted from the body in large mounds on the middle of the pieces as they are drawn from the kiln. Small pimples are often apparent in the glaze when the edges are loose. In these cases of peeling, the body will be left clean. If the dried terra cotta surfaces are sandpapered before spraying, adhesion is good.

A peculiar case of pinholing was thought to be due to the collection of minute quantities of soluble salts at small points on the surface such as projecting grog particles. At these centers, the underslip while still wet was weakened and surface tension caused a small lip of slip to project which would not be downed by the subsequent layers of glaze. Addition of gum arabic to the underslip overcame this difficulty.[1]

During all the cases of peeling of glazes with underslips noted by the author, no case of the vitrified slip coatings separating from the body from this cause has been noted even though they were applied to the same body during a siege of glaze peeling. The addition of a glaze to a slip produces stresses in the slip which tend to loosen it from the body. This can be noted by applying a glaze coating to some well adhering

[1] Hewitt Wilson, "Pinholing and Peeling," *Trans. Amer. Ceram. Soc.* **19**, 209 (1917).

vitrified slip coatings (or in other words, using the vitrified slips as underslips) and tapping with a chisel after firing.

As insurance against repeated attacks of peeling, it is the custom to add some salt of barium to the body to render the sulphates insoluble, according to the well-known reaction. The carbonate is still the most widely used form, though some use the hydroxide and chloride and Staley[1] has shown the desirability of the fluoride.

TABLE III

SOLUBILITIES OF DIFFERENT SALTS

One Pt. Salt	Part of Water Required for Soln.	One Pt. Salt	Part of Water Required for Soln.
Calcium sulphate	495.00	Magnesium chloride	0.60
Calcium carbonate	77,000.00	Barium sulphate	435,000.00
Calcium hydroxide	590.00	Barium carbonate	45,450.00
Calcium chloride	1.37	Barium chloride	3.00
Magnesium sulphate	3.75	Barium hydrate	27.00
Magnesium carbonate	9,400.00	Iron sulphate	3.00

The relatively soluble chloride and hydrate react faster and have a far greater degree of reactivity than the more insoluble carbonate. (Calculate the amount of hydrate, chloride and carbonate, respectively, which can be taken into solution in a plastic terra cotta body containing 25% water in terms of the dry weight.) As the carbonate is removed from the solution by reaction with the sulphate, more carbonate can be dissolved until all the sulphates are rendered inactive. The hydrate is usually more expensive than the chloride. It contains 8 molecules of water, whereas the chloride contains only 2.

a) Reactivity Test for Barium Carbonate The value of barium carbonate for neutralizing soluble salts depends upon its activity when in contact with soluble salts. Activity test:[2] "Weigh out 2 grams of barium carbonate sample and place in 100 cc of a 10% solution of magnesium sulphate. Allow to stand 1 hour at 70°F stirring at 10 minute intervals with a glass rod. Filter and wash with water until no precipitate shows when tested with barium chloride. Wash precipitate consisting of barium sulphate and barium carbonate which has remained unchanged into a beaker and treat with dilute hydrochloric acid. Collect the barium sulphate now remaining by filtering and washing with warm water until the filtrate is free of barium chloride as shown by testing with a drop of sulphuric acid. Ignite and weigh. Correct this weight by subtracting the weight of barium carbonate sample which is insoluble in dilute hydrochloric acid. Convert the weight of barium sulphate into terms of barium carbonate ($BaSO_4$:$BaCO_3$ − 233:197), then this weight divided by the weight of the sample of barium carbonate taken, times 100 equals the per cent of barium carbonate which has reacted with the magnesium sulphate."

The test depends on the (1) concentration of the soluble sulphate salt used, (2) the temperature, (3) the kind of soluble sulphate used, and (4) the time. It is shown that the longer the terra cotta body is aged and the warmer the temperature, the more effective will be the action of the barium carbonate. Grinding a sample of barium carbonate increases its activity but a finer sample of a different variety is not necessarily the more reactive. Barium carbonate which shows a reactivity in the above test of less than 25% is doubtful material. Commercial witherite at $50 to $60 per ton will be about 23% reactive while precipitated carbonate at $70 to $80 will be from 36% to 38% reactive.

---

[1] H. F. Staley, "Use of Barium Fluoride," *Trans. Amer. Ceram. Soc.*, **17**, 200 (1915).

[2] W. L. Howat and G. A. Williams, "Testing Barium Carbonate for Use in Terra Cotta Bodies," *Bull. Amer. Ceram. Soc.*, **6**, 161 (1923).

b) Amount of Barium Salts Needed

(1) The quantity and nature of the soluble salts can be determined by solution in boiling water and filtration through bisque or alundum filters to retain the colloidal clay, followed by an evaporation and quantitative determination of the composition of the filtrate. A rough determination of the quantity can be made with paper filters after a flocculation with a small amount of acid. It has been suggested from various sources that twice the amount of carbonate should be used as that theoretically determined necessary to precipitate the sulphates. The amount will vary with the reactivity of the carbonate and some will be absorbed by the colloidal clay particles. Some is lost by lack of intimate mixing with the salts in the body mass. The amounts commonly used vary from 0.5 to 1.0% of the dry weight of the body. While this is in excess of that required, some insurance should be given to take care of the variability of the soluble salt content in different shipments and portions of the clay bank.

(2) Other methods of a more direct nature have been devised. (*a*) In each of a number of 500 cc bottles is placed 100 grams of clay and enough water added to fill the bottles $\frac{3}{4}$ full. They are shaken thoroughly and allowed to stand until the clay has become finely divided. A 1% solution of barium chloride is then added to each bottle: one cc to the first, 2 cc to the second, etc. Store in a warm place for 12 hours with occasional shaking. After the clay has settled draw off 100 cc of the supernatant liquid through a filter and add a few drops of sulphuric acid. If turbidity develops, the bottle contained an excess of barium chloride. The lowest amount of chloride which develops turbidity is the one to use.

(*b*) The second method is similar to the first save that barium carbonate is added directly to the clay suspensions in small increasing amounts and barium chloride is added to detect the lack of carbonate. If enough carbonate has not been added to take care of the sulphates, the barium chloride will produce a white precipitate of barium sulphate with the excess calcium sulphate.

(3) The soluble salt content can also be determined by electrical conductivity methods using the hydrogen ion concentration apparatus.

As the chloride and hydrate are readily soluble, and an excess would itself produce a coating on the dry clay body, it has been the practice to add an insufficient amount of chloride or hydrate and make up the balance as carbonate. Another method (patented) consists of adding cheap sodium carbonate (soda ash) to precipitate the excess chloride or hydrate. This likewise deflocculates the clay and reduces the water content.

Both calcium and magnesium chlorides are readily soluble and yet do not appear to cause trouble like the sulphates. This may be due to (*a*) a stronger mechanical adhesion of the calcium sulphate crystals to the clay surface, which is rather sparingly soluble and hence not disturbed by the small amount of water added during spraying; (*b*) to trouble caused by dusting during dehydration of the $CaSO_4 2H_2O$ upon heating and a loosening of the underslip from the body, or (*c*) to the high temperature of dissociation of the $CaSO_4$ molecule itself (near 1200°C). Calcium chloride is more soluble and even though it does form a film upon the dry body, it is carried into solution by the water used in spraying. It likewise dissociates at low temperatures. Calcium hydroxide on coming in contact with the air near the surface changes to the carbonate and apparently mixes better with the underslip than the sulphate.

Black ash or the impure soluble sulphide of barium is now on the market and forms a cheaper form of barium salt. It forms barium hydroxide and H_2S when wet and hence is rather disagreeable to handle. It is best mixed with the clay in the dry pan.

c) Methods of Adding Barium Salts

(1) Barium carbonate is commonly added to the clay batch or to one of the clays just before grinding in the dry pan, wet pan or mixing in the soaking pit.

(2) As the per cent of water added to the prepared body in the pug-mill is held fairly constant, the carbonate may be added by means of the tempering water. Two large funnel-shaped tanks of the solution are prepared and used alternately. The weighed amount of barium is placed in a basket screen near the top of the tank and the water runs through this basket, washing the barium salt through the meshes to reduce the large cohering lumps. The prepared solution is kept in constant agitation by the bubbling of compressed air released in the bottom of the tank to keep the sparingly soluble carbonate in suspension. One tank is charged while the other is discharging.

(3) When the pug-mill is fed at a uniform rate by an automatic delivery such as that of a disk feeder, the barium salts can be added as a suspension or solution from a small tube mill which blunges, grinds, and delivers the salt at a uniform rate.

(4) Another method of adding the hydrate is given by M. E. Gates.[1] An agitated solution and suspension of the hydrate is fed by a floating siphon at a constant rate to the pug-mill.

Sprinkling the powdered carbonate over the wet clay in the pug-mill is a very wasteful, inefficient and inaccurate method.

III. Methods of Mining, Handling and Mixing Clays

Most terra cotta clays are soft and the simplest open cut methods can be employed. Some of the middle west clays are mined. A few plants operate their own pits but most depend on contract work or buy the clay outright and receive the shipments in railway cars at their plant.

1. Green Spots Green spots are noticed occasionally with most terra cotta bodies. These are large spreading spots produced by the fusion of some material which has eaten its way to the surface of the body. The green color is that of copper and where concentrated at the center of the spot, the color will be black. Small particles of copper added intentionally produce the same kind of spots. While pieces of copper can be introduced from the screens, it is thought that the majority of the green spots are produced from pieces of copper wire broken from the electric blasting system in shooting out the clay. Aluminum wire ends can now be secured for this work.

J. W. Mellor[2] shows how the same effect can be produced by chalcopyrite and similar copper minerals occurring in the clays.

2. Mixing Terra Cotta Clays on a Large Scale When a terra cotta department is combined with other departments of a large organization, very efficient systems of handling, storing and mixing clay can be arranged.[3] The clay for several different kinds of product, terra cotta, sewer pipe, tile and brick is stored and mixed with the same apparatus.[4]

a) The clay is hauled from the bank in industrial cars to small piles at the edge of a large storage shed.

b) Picked up by a clam shell dipper and stored in large piles under the shed. These are the main storage sheds.

---

[1] M. E. Gates, "Barium Hydrate in Terra Cotta Bodies," *Jour. Amer. Ceram. Soc.* **3**, 313 (1920).

[2] "Pyritiferous Clays," Clay and Pottery Industries, Pt. I, pp. 128-29 (1914).

[3] F. H. Riddle "Gladding-McBean System at Lincoln, Calif.," *Trans. Amer. Ceram. Soc.*, **19**, 102 (1917).

[4] This system has now been changed to that of mixing by disk feeders after grinding. P. G. Larkin, E. R. Curry, Terra Cotta Body Shrinkage, *Jour. Amer. Ceram. Soc.*, **8**, 113 (1925).

c) From the large piles, the dipper elevates the clays as needed to overhead bins on the opposite side of the shed.

d) A gravity feed carries the clay to the measuring car below.

e) The measuring car dumps the proportioned charge through a mixing chute to a conveyor belt below. The latter carries the mixed clay to the dry pan. The mixing chute is large enough to mix the ends of the car load.

3. Simple Method for Smaller Plants The different clays are stored in a line of covered bins, with the railway spur for delivering the raw material on the one side and an industrial car track, on which runs a measuring car, on the other side. Each clay is shoveled to the car to a certain level in a horizontally uniform layer. When full or containing the unit of body mixture, the car is pushed alongside the dry pan and the weighed quantity of barium carbonate sprinkled over the top. A shoveling ledge is dropped into position on the side of the car next to the pan and the lower sideboard is removed first to assure a uniform mixture from top to bottom. The mixture is then shoveled to the pan.

In another system the individual clays and grog are ground separately and stored in bins which taper at the bottom and feed directly upon a horizontally rotating plate. The ground clay and grog flows onto this revolving disk and are scraped onto a conveyor belt in definite quantities. They then receive their mixing in the first pug-mill.

The grog may be ground and screened separately or in some plants it is ground with the clay in the dry pan. Very hard grog is difficult to handle in the latter method which is being displaced in the newer installations by separate grinding systems.

IV. Tempering Methods

1. Dry Pan Pug-mill This system is usually employed in brick and tile manufacture.

2. Wet Pan Pug-mill In this case the grinding and tempering are done together in the wet pan and the tempering finished in the pug-mill which also compacts the clay into bars suitable for handling to the pressers. The grog has been ground separately beforehand.

3. Disintegrator, Soaking Pit, Pug-mill In some of the older plants, the clay lumps are broken in a disintegrator and the mass wet down with ground grog in a soaking pit after which it is pugged.

As the terra cotta body needs high bonding power and high plastic strength the pugging action must necessarily be thorough. The resulting mass must be homogeneous both with respect to the water content and composition, otherwise strains due to difference in structure will give trouble in drying and firing the large and often complicated shapes.

V. Aging

A small amount of terra cotta is used at once after preparation, but the usual custom is to let it stand in a damp room at least 24 hours and often several weeks, the amount in storage depending on the supply ahead of the pressers. Advantages of aging:

1. A tougher body is produced by aging. Bacterial action has a chance to develop. The difference in the wet tensile strength of aged and unaged bodies is just measurable, but at least with some bodies it is large enough to prevent a great deal of cracking in the driers. The body works better in the hands after aging.

2. Standing gives a chance for the barium carbonate to precipitate a greater quantity of soluble salts than if used at once. As the dissolved barium carbonate is changed into the insoluble forms it allows more of the carbonate (which is very sparingly soluble) to dissolve and prepare for action.

3. By standing the water content also has a chance to adjust itself more evenly throughout the clay mass and to soak into the harder clay grains. If the clay stands for any length of time it should be re-pugged to take care of any dry or stiffened parts of the pile. Two days aging followed by a re-pugging is good practice, though often not necessary.

An important point in body preparation is the uniformity of composition and water content produced by thorough mixing and pugging, uniformity from day to day and from week to week.

C. Drafting and Plaster Work

I. Drafting Work

The architect sends the completed plans of the building together with special drawings showing the terra cotta in more or less complete detail. Special ornamental features need special sketches. The terra cotta draftsmen, from the overall dimensions and drawings, cut the terra cotta sections into individual pieces and make full sized drawings of them. Often it is necessary to redesign parts of the construction in order to carry the terra cotta safely and provide sufficient anchorage without undue strain.

Each story and section is given a letter and each different piece a separate number, so that they can be distinguished from all others and can be located on the drawings. As several orders are in the shop at the same time, each piece will also have the order number of the job. These numbers and letters are cut directly in the plaster with the exception of those special pieces which are molded directly in the plastic clay or made up at the miter bench.

Approval by Architect The architect usually approves the drawings before they are put in the shop. This is especially true of special ornamental designs, original with the architect.

Special models are approved by the architect either by a visit and inspection or by photograph.

II. Modeling and Mold Making

Modelers are a skilled class of craftsmen and usually have a room separate from the general plaster shop. High ceilings and well lighted rooms are necessary. The work is done on benches, stools or large easels.

The modeling clay is usually the regular terra cotta clay mixture containing no grog. After the ornament is modeled it is kept in the plastic state with damp cloths until the mold is cast over it. Plasticene is too expensive for the large pieces. Flexible materials like glue are sometimes used for very complicated shapes.

1. To Make a Single Ashlar Mold An ashlar is a plain rectangular piece having variable dimensions but with no ornament.

a) The Model On a smooth (usually stone) table lay out the dimensions of the face using the shrinkage rule. Place wooden or soaped plaster sides on these dimension lines and brace firmly. Add handfuls of plastic plaster to the interior forming a hollow box with the inside unfinished. When plaster has hardened, remove sides, invert model and trim, producing a duplicate in plaster of the finished piece save for expanded dimensions and lack of partitions.

b) The Mold Place the model face up on the table and soap. Within the proper sides and end stops cast each mold side separately, soaping the ends of each side as cast. Then with the sides of the mold in position around the model, cast the bottom on top of the rest. When hard, separate the four sides and the bottom from the model, trim, and fit the five parts of the mold together, and provide a loop of band

iron to hold the sides in position. Wooden wedges will take up the slack of the band iron. The model is discarded or used to make more molds. The mold parts are reinforced with strips of wood or iron.

A simple ornamental edge such as an "egg and dart" or "lamb's tongue" can be placed on an old ashlar model. Press the ornament in sections from modeling clay, using small stock molds and arrange these clay pieces in the proper position on the ashlar model. Then cast the mold over the whole as before.

Complicated models are carved directly out of the plastic clay using as much old plaster work for foundation parts as possible.

2. Models by "Profiles" If there is a repetition of a number of pieces in the same course, having the same profile of face, time and expense can be saved by making a profile of this face in zinc or iron sheets and drawing the same through soft plaster. The crudely fashioned model is set on the table and the profile drawn across the face by hand or mechanical operation. Wet plaster is thrown on the low places and the excess removed by the profile in passing. Such a model may be used as a foundation for carving further ornamentation. These profiles may also be used for radial ornament, being pivoted by a long wooden radius to a distant center point.

The profile is cut from zinc or iron sheeting with shears to correspond to the draftsman's full sized drawing and braced or nailed to a wooden frame.

3. Old Molds It is quite a problem to economically dispose of old molds and models. In the state of Washington, the Portland cement plants take the majority for use in their cement mixture. The iron reinforcing rods are removed, straightened and used repeatedly.

There is also an accumulation of slop plaster from washing buckets, etc. This is very difficult to settle or dry. In lime-poor regions it has been used for agricultural purposes.

4. Checking the Terra Cotta Through the Shop While the use of stock terra cotta is increasing it is still a negligible factor in most shops. Each piece is given the letter of its course and a number in the course. As the presser turns the clay piece out of the mold, he puts a ticket on the side of the wet clay with a tack. Each order has its number and a different colored ticket. These tickets remain on the pieces until loaded on the truck for spraying. Besides the ticket, each piece has its order number and position number engraved on the side in the clay itself from the mold. Otherwise the fitting shed man would be lost. Drawings accompany the ware through the shop and go to the mason foreman or contractor on the building.

D. Pressing and Finishing (Molding the Body)

I. Pressing

1. Power Methods While a few power presses have been used, they are not generally credited with being successful from an economical standpoint. These different systems have been tried.

a) Compressed Air Spattering the plastic clay onto the sides of the mold with compressed air. A plunger pressed clay out of a cylinder into a flexible reinforced hose from the end of which it was driven with compressed air into the mold in small lumps. The partitions were built up in the ordinary manner. Too much power was required to force the clay through the hose and the grogged body gave too much abrasion and wear. This method is similar to the present cement "gun."

b) Direct Plunger Action The reinforced plaster mold was set in position on a press beneath a double plunger. After the required bat of clay was thrown into the mold, the plunger entered from above and squeezed the clay up and around the sides. The space between the plungers formed the single partition. This

is a practical method for making a large number of small ashlars of the same dimensions such as would be required for stock terra cotta. Machines have been developed in recent years for pressing saggers and these could probably be adopted to simple terra cotta pieces of same size and shape.

c) Pressing by Gasoline Explosion A line of molds on a roller table is pressed loosely by hand and the partitions placed. Concerted action is obtained by a line of pressers, each man doing but one portion of the pressing as the mold passes him. The final pressing is done in the machine. The pressing or explosion chamber is in line with the roller table and as soon as the mold is in position in the machine a metal sliding door is dropped on each side. In a chamber above, gasoline vapor and air are mixed and compressed as in an auto engine and when the pressure reaches a certain point, two valves leading into the explosion chamber, open. As the charge escapes into the lower chamber, it is exploded by spark, directly into the open mold. The resulting pressure goes over 200 pounds per square inch and is supposed to give the final and uniform squeeze to all parts of the clay in the mold. As the sliding doors fit but loosely, the pressure drops immediately. The doors are then opened and the mold is pushed out onto another roller table above which is a hot air duct with numerous pipes blowing air into the molds. By the time the pieces reach the end of this table they are supposed to be dry enough for stripping.[1]

Shrinkage and drying strains are to be eliminated by this high and uniform pressure The pressure on the inside and outside of the mold are the same so that air in pockets between the clay and the mold must be driven into the porous plaster itself in order that the clay come in contact with the mold. As the explosion takes place directly above the open mold and clay, it is applied first to the inside of the mold before it has a chance to adjust itself on the outside. The idea of a number of pressers working together with each responsible for a small portion of the work tends to speed up production. This system has been used to great advantage in other industries.

2. Hand Pressing Practically all architectural terra cotta is molded by hand pressing. The plastic clay is brought from the aging cellar or pug-mill and stored in a covered pile beside the presser. In some shops the presser works on a small bench with the clay supply in a fixed position beside him. In others, he moves from one mold to the next as they lie on the floor itself. In pressing he tears or cuts a lump of clay from the pile. If it is for the face, it is rolled or pounded on a damp plaster board until the surface is smooth and the grog particles covered with a thin coating of clay. This bat is then thrown into the mold with the smooth side next to the plaster. If one is not large enough, other bats are slapped in until the face and sides are covered. Where the smoothed side of the clay bat lies unbroken on the plaster, it needs little further attention. However, at the junction of two bats, particularly where the smooth surface has to be broken to cover the plaster, the surface will be rough and groggy and needs further treatment. Thorough beating of the clay as it lies in the mold with a cloth covered plaster bat will drive out the air blebs and pressing holes and cause a clay film to work its way around the exposed grog grains so that they do not show on the lower surface. A similar action takes place when the surface is rubbed with a steel trowel.

Many failures of terra cotta in the wall are started from air blebs, thumb marks and other imperfections in the body structure. Corners should not be pushed in with the thumb, but a solid roll should be pounded in with the fist. Channels should be scooped out for partitions, which should be welded to the walls by working in extra rolls of clay along the contact. Ortman suggests the use of clay having a lower rate of shrinkage for partitions.

---

[1] Major Gates, U. S. 1,482,646. Feb. 5, 1924.

The side walls and partitions are carried slightly above the mold and the excess cut off with a wire to provide a smooth bearing plane. As soon as enough water has been removed so that the piece will bear its own weight, without warping or sagging, it is revolved on a sanded board and the mold stripped. Large heavy walls, in danger of sagging, should be revolved in a vertical plane. If the piece is left in the mold too long, shrinkage will cause tension or cracking around those portions of the plaster mold which project into the clay.

3. Absorption of Water by the Mold If the clay has given up enough water to the mold, so that the piece can be "turned out" without distortion and bear its own weight, the face, which has lain next to the mold, will be in a stiffened condition considerably beyond its best plastic condition. The average of two trials gave us the following results using dry plaster and clay masses of an inch thickness, covered with a glass plate.

	a	*b*	*c*
Time of contact between plaster and clay in minutes.....	10	20	30
Per cent water absorbed by plaster in terms of total water content..	5.9	10.1	10.5
Per cent water absorbed by plaster in terms of dry weight of clay...	2.5	4.3	4.4

And this water is not evenly distributed throughout the mass. The average of seven trials gave between 2.0 and 3.0% (in terms of dry weight of clay), less water in a thin section about 0.05 inch thick which had been against the plaster than sections taken from the interior and the outer surface. Undoubtedly, the skin of clay immediately on the surface contains even less water and is approaching brittleness.

a) Drying As a clay mass dries from the best plastic state, it gradually loses its moldability and becomes more brittle, although its strength is increasing at the same time. In this latter state, as the plastic working properties decrease, the clay also loses the ability to adhere when broken faces are pressed together. This is probably a gradual change. The rate of losing water and the minimum amount of water needed for plasticity or moldability are properties peculiar to each clay. The safe working range is undoubtedly less for bodies containing coarse non-plastics such as terra cotta grog than for bodies in which the non-plastic content is in the state of ground feldspar or flint.

II. Methods of Finishing

After the mold is stripped off the piece of terra cotta, it is usually allowed to stand and dry or "stiffen" before "finishing." This interval will vary from one to twenty-four hours or even more, depending on the practice which has been found best for the body.

There are two general methods of "finishing," also, combinations of the two: 1. Finishing with "steel," such as a trowel or a special tool for ornament, edges or tooled surfaces. 2. Finishing with a water brush, which is equivalent to the sponging of pottery in the leather hard state. Preceding the water brushing, the edges, corners and lines of the piece are straightened and the surfaces cleaned of the larger irregularities.

1. Finishing with Steel (The dry method) Rubbing a smooth trowel over a piece of clay in its best plastic state is similar to pressing a column of clay through the die of a brick machine. It is a smoothing pressure, followed by a release. Exposed particles of grog are pressed down by actual contact with the tool while the plastic clay, with ability to flow, is squeezed up and around the grog grains until they are embedded, save for that point which is in contact with the tool. They are not completely buried; you cannot see them easily, but you can feel and hear the grating or scratching as the tool passes over the surface.

If the clay mass has dried until brittleness and the consequent decrease in moldability has developed, the clay is torn as it is pressed up around grog grains or as the grog

grains are moved slightly in a horizontal direction. Though pressed together, a great many of these torn surfaces are not firmly bonded again and the cracks are easily reopened by the stresses which accompany drying and firing.

It is easier to smooth a surface approaching the leather hard condition. It resists visible deformation and "polishes" easily. Naturally there is a tendency for a presser to delay finishing his ware until it reaches the state in which it can be done most easily and quickly.

2. Finishing with Water Brush A soft flat brush is dipped in water and the excess water is pressed out on the edge of the bucket. The surface is then rubbed thoroughly. This action:

a) Knits the torn surfaces and fills the minute cracks.

b) Increases the water content of the surface so that there is less difference between the interior and the surface.

c) And either picks up and removes or partially buries in a firm plastic mass of clay the exposed grog grains.

d) Water brushing is more rapid than steel finishing.

e) It can be used for ashlar, plain or tooled finish and for ornamental work. A soft, sponge may be preferable to a brush for delicate ornament.

f) As in the case of steel finishing, if drying has progressed beyond a certain stage this method of soaking the surface is ineffective as a preventative of slip cracking.

E. Drying

Until the advent of the humidity drier, the drying department was the weak point in the chain of terra cotta manufacture. The drying period is usually divided into two parts: (1) Stiffening and (2) final drying. Some bodies will be stiff or hard enough as soon as finished to withstand the transportation and jolting strains to a drier for final drying.

I. Preliminary Drying

Preliminary drying while the ware is still in the mold is now a common practice by the use of overhead flexible air pipes from which warm air is forced around the partitions and backing walls of the ware. This process shortens the time in the molds, and warms the interior of the piece for more rapid and uniform drying. Stiffening in the open press room is also assisted in different shops by warm blasts of air forced from pipes beneath the drying floor, steam coils beneath the floor or overhead. The warm air of the room is often kept in circulation by overhead fans.

II. Final Drying

The final drying may be performed in many ways. At several places the pressing floor is converted into a drier at night by the use of steam or hot air pipes beneath the floor or the circulation of hot air throughout the room. This method saves extra handling but is usually supplemented for the larger ware by some type of a box or room drier where the temperature can be raised to nearly 140°F. The floor drier is very useful for small quickly drying ware where cracking troubles are negligible, but requires a large floor space and is often uncomfortable for the pressers.

The majority of terra cotta manufacturers use some type of a room drier where the conditions of temperature and often humidity can be carefully regulated and adjusted to a standard schedule. The older and simplest types are simply hot boxes heated by steam pipes or hot air. The smaller ware is placed on racks as high as they can be lifted comfortably while the larger pieces are placed on the floor. It is best to tilt the large flat ware to the angle of slip and in this way counteract the frictional resistance of the weight of the piece in contracting along a horizontal plane. The rate of safe drying for

the differently sized pieces of each body should be determined and definite time-temperature schedules followed to insure continuous economical drying.

As the water must pass out through the sides and face of the ware, the center partition near its junction to the face of the body is the slowest to dry. Holes cut into the boards to allow penetration of air from beneath are no good unless a circulation of air is provided into these closed holes. As cracking results from unequal shrinkage and rate of drying, a large portion of the cracks will be found through the center close to the wet center partition. The strength of clay increases with the removal of water and shrinkage. If a tension develops it is most likely to be caused by a crack in the weakest section which is likewise the wettest section.

With poorly designed bodies, it has long been the custom to retard the drying of the fastest drying sections, such as the edges and corners or projecting members by covering with a burlap sack. With some bodies it has been necessary to retard the drying of the whole exposed surface until the interior had a chance to slowly adjust itself. This procedure is a crude form of humidity drying, whereby the humidity of the atmosphere under the sack is raised above that of the outside air while the interior temperature of the piece is slowly raised. Complete sacking is a very poor excuse for humidity drying because it neglects the principle of rapid circulation and greatly increases the time of drying.

1. Humidity Driers The introduction of humidity driers has been one of the greatest single developments in the terra cotta game. It is a big step closer to exact control of all the conditions necessary for successful and rapid drying. The important factor in the control of the humidity and temperature is the rapid circulation of air to all parts and surfaces of the ware. This is done by powerful fans or blowers, supplemented by the injector principle as used by the Carrier Engineering Co. It is necessary to so rack the ware that ample circulation is secured around each piece and better still if the piece can be placed on edge with the back exposed.

The ware is first subjected to a heating period with the humidity high so that very little evaporation takes place. By this treatment the temperature of the interior is heated close to that of the exterior and the vapor tension of its water content raised. Next, the humidity of the surrounding air is gradually decreased by raising the temperature. Drying now begins under control and the ware dries rapidly and safely. Since the transfer of moisture depends on the difference between the vapor tension of the water content of the air and that of the ware, a regulated amount of moisture absorption by the air can be obtained. Evaporation from the surface requires heat, cools the surface and lowers the vapor tension of the surface moisture. The moisture content of the interior of the clay mass now has a higher surface tension and moves to the surface to equalize the vapor tension difference. Thus, in humidity drying, the vapor tension throughout the clay mass tends to more nearly approach that of the surrounding air and is given the best opportunity possible by rapid circulation and removal of stagnant films and air pockets.[1] Regulation and control instruments have been devised to make the whole process automatic. The high humidity for the first period of the drying is obtained by steam jets although some types of the first driers merely recirculated the air carrying the moisture picked up from the ware itself. Savings are reported not only in time of drying (18 to 24 hours) and freedom from cracking but also in steam consumption and floor space.[2]

---

[1] A. E. Stacey, Jr., "Theory of Evaporation with Reference to Effect of Air Velocity and of Moisture Diffusion," *Jour. Amer. Ceram. Soc.*, **8**, 457 (1925).

[2] A. E. Stacey, Jr., and H. B. Matzen, "Ceramic Driers and Drying," *Jour. Amer. Ceram. Soc.*, **8**, 525 (1925).

For special work requiring the accurate fitting of engaging members such as in column work, it is well to dry the units together in the proper positions of engagement. An end resting on a board is retarded in shrinking by the friction of the bearing surface and will be larger than the upper free drying end. Shrinkage is greater in a vertical dimension than in the horizontal. In other words, the clay particles will adjust themselves along the lines of least resistance during the shrinking period and linear shrinkage varies with conditions.

F. Slips, Glazes and Spraying

I. Storage, Mixing and Identification of Raw Materials

The raw glazes and slip materials should be bought in large quantities to insure uniformity over a reasonable period. After the chemical has been thoroughly tested, at least a year's supply should be purchased.

The barrels and sacks should be piled in such order that they can be easily counted for invoicing. The storage room should be dry to prevent rotting of the sacks and to hold the moisture content down to a minimum. Five per cent water in feldspar and 10% in ball clay causes variations in the batch composition and is by no means an uncommon condition. Always weigh the slip and glaze materials in a dry condition.

Ball clays, unwashed and shipped just as they are dug out of the clay bank, are the most variable of the raw materials. One or two large chunks will supply the requirements of a mill of glaze. You are relying on this ball clay content for adhesion, stickiness and strength. One or two bad lumps can thus greatly disturb a mill of glaze which in turn will cover a considerable area of terra cotta surface. It is a good practice to keep crushed ball clay in 5-10 ton lots prepared ahead. Remove the ball clay from the sacks to a clean floor space and crush it with a tamper to at least two-inch size. Mix the whole by shoveling and store in a bin or return to the sacks. Keep record of the quantity so treated.

1. Identification and Sampling On each container of each shipment received should be placed a tag showing (1) the material contained and (2) the lot number. Note should be made in the chemist's record of the (1) shipper and (2) the date the shipment was received.

Each lot as received should be sampled in some approved method. See AMERICAN CERAMIC SOCIETY's Standard Sampling Methods. The gross sample should be reduced in size and used in one or more of the regular slips and glazes, when nothing else is changed but the material to be tested. These small sample batches should be prepared in the usual way, sprayed on large pieces and fired with the regular ware. Each lot of material should be consumed before starting on the next lot with the higher number, except in case it is thought necessary to save a small batch for emergency. In this way these unknown troubles not revealed until the ware is drawn from the kiln can oftentimes be traced to the source or better can be prevented.

Mix the prepared slips and glazes in large quantities.

II. Preparation of Slips and Glazes

1. Process of Preparation The regulation of the water content should not be a matter of guess either by the laboratory man or the sprayers. The best workable specific gravity should be determined in advance by the chemist for each slip and glaze and held constant throughout the job.

a) Dry Materials Either use artificial heat or keep stored in sufficient quantities in a dry room to insure low water content.

b) Water to Mill Place a water tank above the mill, so that it can drain directly into the mill. An outside graduated glass tube for reading half gallons gives you sufficient accuracy for a charge of 100–500 pounds of dry materials.

c) Slip Storage Keep stored in covered tanks which allow but a minimum evaporation. Before starting any order, grind or blunge ahead as large a quantity of all the slips and glazes to be used, as possible, preferably enough to finish the order. If the separate mills cannot be placed in the same tank, mix thoroughly and store in smaller tanks.

2. Control of Specific Quantity Check the water content by weighing a portion of the slips and glazes in a ground glass stoppered bottle of about one pint capacity. Check this every few days. With the same specific gravity bottle the specific gravity does not have to be calculated save for record or for a new bottle. Control can be maintained with but the weights of the bottle plus slip.

Establish the specific gravity or water content first before adjusting the viscosity. If the weight of a given slip is too low allow it to settle and siphon off some water. If too heavy add water.

3. Control of Viscosity Once the standard water content is adjusted, do not add water to the slip or glaze unless, because of drying and evaporation, water has been lost. As the sprayer sweeps across the face of the terra cotta with his spray, he soon acquires definite motions. If the water content varies, these same motions and rate will give variable thicknesses of dry material on the surface sprayed An intelligent sprayer will pick into the glaze, drying on the ware, enough times during the day to know the thickness of his coatings. But the average sprayer must have every possible precaution taken by others to make his job as near fool-proof as possible. Spraying is usually a dusty, dirty job, where the men are rushed and get only average pay. But it is perhaps second to the kiln firing alone in ease and quickness of spoiling ware.

There are only two troubles connected with spraying, thick and thin or heavy and light spraying.

Therefore use electrolytes for the regulation of viscosity, not water. Acids such as hydrochloric and acetic increase the viscosity and alkalis such as soda ash thin the slips and glazes. Glazes with low clay contents and high amounts of the carbonates, feldspar and zinc oxide are more easily affected than slips of high clay contents.

The viscosity of a glaze is a variable factor, depending on the time of grinding, aging. addition of gum and the composition. When a glaze, containing no electrolytes, is freshly ground, it is usually more viscous than after standing a few days. This may be due to enclosed air content. If it stands long enough, there is often a fermenting or souring action which is usually accompanied by a thinning of the glaze.

The viscosity of slips and glazes containing gum is more difficult to control. The gum appears "to exercise a protective influence on the stability of the system" and the slips are less affected by acids and alkalis. Likewise they are more difficult to maintain at a constant viscosity.[1]

III. Spraying

A convenient method of feed to the sprayers can easily be arranged if the laboratory is above the spray room. The glaze man pours the glaze into funnels or tanks which feed by gravity through a rubber hose to the sprayers below. At some plants a bucket of the glaze is elevated by rope and pulley to the ceiling above the sprayers. Other sprayers carry a quart cup in one hand from which the slip is sucked through a small pipe directly into the spray gun. Compressed air bubbling through the slip is a convenient method for keeping the same stirred and of uniform composition.

1. Handling the Ware during Spraying a) After the ware comes out of the drier each order is placed by itself in a pile near the sprayers. Several pieces are placed together on a truck and pushed alongside the sprayers

[1] See Bleininger "Effect of Alkalis on Clays," U. S. Bur. Stand., *Tech. Paper*, No. 51 p. 37 (1915).

who turn the trucks or walk around the pieces so as to cover all the necessary surfaces with glaze. One man puts on the underslip and the second man the glaze. The helper loads and unloads the trucks. The ware can in some cases be pushed straight to the kiln and set for firing. Some glazes need a drying period before setting as the glazed surface must be touched in handling large pieces. Gum arabic aids in strengthening the glaze when dry and avoids unnecessary mutilation.

b) Revolving Stands Each piece is carried from the pile to a small revolving table in front of the sprayer. Each sprayer can work two stands. The slips and glazes must be of the fast drying type. For this work smaller guns are used and the sprayer works closer to the piece.

c) Multiple Revolving Stand This consists of a large revolving ring twenty feet in diameter and operated by motor. On the circumference are numerous revolving stands each holding one piece of ware. The sprayer sprays the piece, turning it around on its stand as it passes him. One man will give it the first coating and a second sprayer the second coat.

The dust from any method of glaze spraying may be collected in hoods and used again as the base glaze for colors.

2. Spraying Technique

a) Wet Spraying If a smooth surface is desired with a "standard" or vitrified slip at a specific gravity around 1.350, without the addition of any alkali, it is necessary to apply the slip until it comes to a water finish (glistens with water). That is, the slip contains enough water and it is supplied to the terra cotta surface at such a rate that it will form a smooth watery coating. If there is less water or the slip is supplied at slow enough rate, the evaporation into the air and soaking into the body will prevent the water surface from forming. For slips which only vitrify and do not flow and heal themselves like glazes, the wet method should be used to produce smooth surfaces. Large spray guns are conducive to wet spraying.

The type of spraying varies with the composition of the coating applied. The higher the clay or plastic content the more water required for fluidity and the easier it is to get the water finish. The water content can be reduced by alkali deflocculation as will be explained under "dry spraying" and also by the use of calcined clays and calcined zinc oxide and other ingredients received in a very finely divided form but which become agglomerated by preheating. Reduction of water content means faster drying and a reduction of shrinkage with a greater freedom of drying cracks on the surface of the terra cotta, particularly in the internal angles.

Evenness of spraying can be accomplished by application of thin coatings in successive treatments, waiting for each to dry until it can be touched with the finger without marring the surface. A sprayer develops a slow even motion of parallel lines across the piece first in one direction and then another. If too much slip is added in a single application, puddles will develop on horizontal surfaces, ornamental depressions will be flooded and "runs" will form on vertical surfaces.

If a coating is allowed to dry to whiteness and then another application is made, air bubbles from the pore spaces of the dry coating will emerge as blisters in the wet second coat. The harmfulness of these will vary with flowing and healing qualities of the overlying coating in the kiln.

The spraying department is one of the three departments which can very easily cause considerable variation in the color and texture of the terra cotta. It takes considerable experience and testing checks through the kiln before a sprayer is well "broken in," to do uniform work. In the usual small plant several changes a day may be necessary from one order to another with a consequent change in the method of application as various underslips, matt gloss glazes, vitrified slip coatings and the multitude of spots, granite and pulsichrome coatings are applied.

If the underslip is too thin, the color will be darkened or blued by the darker color of the body showing through the glaze. With some light brown bodies, it is almost impossible to get a good white color.

If the underslip coating is too thick, it may cause crowfooting, pinholes and peeling or flaking of both coatings from the body.

If the glaze is too thin the fired glaze will be dry and rough or look as if it were underfired.

If the glaze is too heavy, crowfooting, cracking and pulling away from the underslip, pinholing and crazing may result. Some glazes have a very narrow range between a dry appearance on the one hand and crazing with thick coatings on the other.

Ornamental work and internal angles require a different procedure from ashlar and plain surfaces. In attempting to get slip or glaze into a depression an excess will be added to the surrounding surfaces. Hence it is best to spray the ornamental features first and make certain that the depressions have at least a medium coat. If too much is added, blow them out with the air alone. The piece can be treated as an ashlar in succeeding coats and the high points of the ornament alone considered. It is better that the internal angles have a thin coating than a thick one.

b) Dry Spraying That in which a water finish does not form but where the water content is so low that the slip is deposited on the surface as dust. It is not a good method for slips which do not fuse and smooth out during firing. Their surface will be still rough and porous after firing.

Procedure: For Under Slip and Glaze (1) By means of soda ash, sodium silicate, etc., reduce the water content of the glaze until the spray from the nozzle forms a dry coating rather than a water finish unless the nozzle is held on one spot. This means that the water content will be from 50 to 70% of the dry contents, depending on the composition of the glaze and the nature of the spray gun.

(2) Spray the underslip as follows. After removing all loose surface material by blowing and brushing, blow the slip swiftly over the entire piece, filling all body imperfections, minute cracks and ornamental internal angles. Shut off the slip, hold the nozzle close to the surface and blow it dry, removing all the excess slip from the internal angles and cavities. This puts a coating of slip all over the surface and helps avoid the pink spots of thin coatings. To tone up the piece the ashlar surfaces and the exposed portions of the ornament may need an additional coating. This can be applied immediately with the gun held at a distance. Care should be taken to avoid wetting the internal angles at this time.

(3) Allow the underslip to dry hard. You are not going to soak it with wet glaze so it can dry and crack before glazing.

(4) Spray glaze around in the ornamental work with the nozzle held close, blowing out the excess.

(5) For the bulk of the glaze coating, hold the nozzle well away from the surface and spray dry, going over and over the piece until the coating is heavy enough. Do not hold in one spot until the water finish develops.

(6) Gum should be used in glazes for this method of spraying, otherwise the dusting is excessive.

c) Results (1) Dry spraying is slower than wet spraying.
(2) It takes a little practice and is not fool-proof.

(3) It gives excellent results in filling angles with heavy glaze without cracking. The glaze is added in a firm powder form to the dry underslip which has developed its drying cracks. This powder, containing so little water, will not crack in drying and is in position to melt and fill up all the underslip and body cracks.

(4) A glaze is needed which will develop and melt several cones below the finishing temperature. Otherwise it may be dry and rough.

(5) It is not applicable or necessary with those glazes whose viscosity is low during firing and which heal imperfections well.

IV. Underslips

1. Purpose To provide a white, semi-clay intermediate layer between the buff colored porous terra cotta body and the fusible glaze; to provide a portion or all of the opacity required to hide the body; to act as a strong flexible medium between the glaze and body and enable the former to resist cracking in small local spots on the body. A good many glazes, especially those of the high temperature stoneware type, are viscous at the maximum heats and do not flow well or heal small imperfections and cracks formed during drying and the early periods of firing. In fact, their surface tension is strong enough to widen cracks and to pull the broken edges apart. Some of the older glazes also contained large quantities of plastic clay material and the shrinking and cracking troubles were high. The terra cotta body with its large content of coarse grog is a rather difficult surface to cover. Its surface shrinks and moves in an irregular fashion and small cracks develop around the large grog grains near the surface. The glaze before fusion has a low mechanical strength and small cracks in the body will continue through the glazed surface. Unless the glaze is of the fluid type such as the low temperature or raw lead fritted glazes, surface tension will widen such cracks. Glazes which are fluid and of low surface tension will flow into such imperfections and hide them. The high clay underslips thus provide an intermediate flexible layer which can give and take with the body and ease-off the strains from the glaze. Its non-plastic content such as feldspar, flint or whiting is finely pulverized and does not produce local cracking. The veneering of fine grained underslip changes the glazing problem from that of a coarse grogged fire clay surface to something near that of a finely washed stoneware or white ware mixture where the glazes are applied directly to the body.

Several terra cotta companies apply an opaque lower temperature fluid glaze directly to the body and in most cases have better contact between glaze and body. They are not troubled with some of the forms of peeling encountered with the high clay underslips for the glaze has the opportunity of tieing directly into the body surface by solution and fusion.

TABLE IV

TYPICAL UNDERSLIP FORMULAS (For High Temperatures)

	1	2	3	4
Clay[1]	80	40	45	57.3
Whiting	8	5	—	8.2
Flint	12	35	10	20.5
Feldspar	—	20	—	14.0
Cornwall stone	—	—	45	—
	100	100	100	100

Number 1 underslip is useful on bodies difficult to cover. The high clay content, particularly if about one-half English ball clay is used, gives a very tenacious coating.

[1] This represents mixtures of the ball and china clays. A large number of terra cotta plants still prefer the English ball clay because of its excellent plasticity, tenacity and flexible qualities, combined with its lower temperature of dense vitrification. Alone, it will give an ink-proof surface at cones 6-7 with the minimum of cracking. Its color is poorer than most American ball clays for it fires to a decided cream color.

The other slips are similar to various white-pottery bodies and fire to harder structures. Some are applied as a very thin coating in one application and do not affect the color very much. The plastic, dry and fired properties of each of these underslips can be varied considerably by the use of different clays, feldspars or the use of Cornwall stone to replace the feldspar. The action of flint and lime from different localities may show slight differences in color and slight physical differences due to different fineness of grain. One or 2% of a soluble salt like borax or soda ash is often added to produce better adhesion to the body by crystallization on drying but the advantages of this procedure are questionable.

V. Glazes

1. High Temperature Types, Cones 3 to 7

TABLE V

GLOSS GLAZES (Bright and Glass-like)

	1	2	3	4	5
Feldspar[1]	60.0	39.8	58.0	43.3	54.7
Flint	12.0	19.7	18.7	29.3	7.4
Whiting	12.0	10.6	5.2	6.3	17.7
Zinc oxide	6.0	5.1	6.2	——	8.0 (white lead)
Barium carbonate	——	8.5	5.2	5.7	——
Magnesium carbonate	——	1.4	——	1.8	——
Clay	10.0	14.9	6.7	13.6	12.2
	100.0	100.0	100.0	100.0	100.0

J. W. Mellor gives the following molecular formula for "mixed" Cornwall stone:

$$\left.\begin{matrix} 0.315\ K_2O \\ 0.143\ Na_2O \\ 0.180\ CaO \\ 0.030\ MgO \end{matrix}\right\} \begin{matrix} 1.0\ Al_2O_3\ 7.15\ SiO_2 \\ \text{Mol. wt. } 582 \end{matrix}$$

Numbers 4 and 5 are zincless glazes for cone 6 to be used in cases where a green from chromium is desired. Even with the introduction of white lead, these zincless glazes will be more refractory, and will not have a very wide fusion range at cones 6–7.

It is customary to calcine the zinc oxide and portions of the china clay to reduce the water content, the dry and fired shrinkage of the glaze after application, to hasten the drying and to prevent internal angle cracking.

TABLE VI

HIGH TEMPERATURE MATT GLAZES (Cones 3 to 7)

	1	2	3	4
Feldspar	54.1	51.6	64.3	47.8
Flint	6.0	5.6	1.9	——
Whiting	13.7	18.8	8.9	10.4
Zinc oxide	4.0	8.6	15.2	8.1
Barium carbonate	6.1	——	——	5.6
Magnesium carbonate	2.1	——	——	1.6
Clay	14.0	15.4	9.7	26.5
	100.0	100.0	100.0	100.0

[1] Parts of the feldspar are often replaced by English Cornwall stone. With the stone introduction, the flint and clay content should be lowered.

The easiest method of producing a matt glaze from any given gloss glaze is to raise the alumina content or the alumina-silica ratio by reducing the free silica (the flint) and raising the clay content. The true matts are not matts of immaturity which contain so much undissolved material bound together with a silicate glass, that the reflecting surface is softened. The true matts form glassy solutions which can be seen if draw trials are removed from the kiln at the high temperatures and develop their matt texture during the cooling process by crystallization of mullite ($3Al_2O_32SiO_2$) and other crystalline compounds of lime, zinc and barium. It is believed that the mullite crystals are the quickest to form but undoubtedly the others have some influence. Matt glazes can be produced with lead oxide, alumina and silica alone at low temperatures[1] or at very high temperatures with alumina and silica alone as can be demonstrated by the cone fusion of Orton cones above cone 32 even with very rapid cooling.

To maintain the matt texture of a given matt glaze a greater alumina-silica ratio is needed if the temperature is raised or if the rate of cooling is increased. Many matt glazes from large commercial kilns often will be glossy in small laboratory kilns. Differences in the degree of glossiness or mattness can be noticed in commercial kilns of different sizes or even in the same kiln if one portion receives a higher temperature than another. Different shipments of feldspar containing different percentages of free quartz will often "throw" a matt glaze to a satin or gloss. Matt glaze No. 4 will be matt in laboratory kilns at cones 6–7 with a 10-hour cooling. It represents an extreme limit not necessary for ordinary commercial work. All degree of texture from dull matts to the glosses can be made by mixing gloss and matt glazes. Some architects require intermediate textures of a satiny sheen.

2. Low Temperature Glazes

The intermediate temperature glazes (cones 3 to 5) are very similar to the cones 6–7 glaze compositions but care must be exercised in regard to the fluxing effect of the feldspars. The latter are selected to produce a low temperature flux and several feldspars are often mixed. Soda feldspars are advantageous.

For the low temperatures (cones 02 to 3) it is necessary to use lead oxide or fritted glazes with lead, the borates or increased amounts of the alkalis. The raw lead glazes are dangerous to the health of the sprayers and are not used. The low temperature fritted glazes are often used without the underslip which seems to be necessary with the modified Bristol glazes. These glazes flow and heal themselves better than the more viscous feldspar glazes and can be made opaque enough with tin oxide or other opacifiers.

TABLE VII

GLAZE EXAMPLES (Low Temperature Fritted Glazes)				GLOSS GLAZE (A Portion is Fritted)	
Gloss Glaze	Frit	Glaze		Feldspar	46.0
Borax	9.4	47.0	Frit	Clay	6.4
Soda Ash	6.2	18.3	Feldspar	Flint	11.0
Clay	14.4	9.4	Clay	White lead	21.3
Flint	43.8	7.0	Whiting	Whiting	10.0
Whiting	12.2	6.4	Tin oxide	Zinc oxide	5.3
Magnesium carbonate	4.2	11.9	Flint		100.0
Zinc oxide	9.8				
	100.0	100.0			

[1] See Staley and Hewitt, *Trans. Amer. Ceram. Soc.*, **19**, 659 (1917).

The frit portion of these glazes is melted in a furnace similar to that described by H. F. Staley,[1] ground in ball or drag mills and mixed by grinding with the raw ingredients of the glaze.

3. Glaze Fit and Glaze Defects

The most common glaze defects are: Dry surface due to too thin a coating, thin glaze on edges and ornament, crawling, internal angle cracking, crowfooting cracks, pinholes, peeling, dunting, crazing and shivering.

a) Thin Glaze Too thin a coating of glaze is a spraying trouble. Thinly glazed edges may be due to a minimum fluidity of the glaze during spraying (too much water or degree of dispersion by alkali) or to a low viscosity of the glaze during firing. Rubbed edges are often made by the kiln setters in moving the ware from the trucks to the kiln. Gums, such as the tragacanth or the cheaper forms, gum arabic sorts or dextrine, are often used to produce a more elastic coating during drying and a harder surface when dry.

b) Glaze Cracking Crawling of the glaze from small cracks in the body or underslip, indicates that surface tension has been active after fusion. The Bristol or cone 8 stoneware glazes, high in feldspar and clay with low accessory flux content, are prone to crack easily and be very viscous at cone 6. At higher temperatures they become fluid enough to flow and heal some of their imperfections. The introduction of more fluxes to lower the fusion point four or five cones below the finishing cone, is one way to stop crawling. The initial cracks may occur in the body, underslip or glaze itself, but if a viscous glaze is once cracked, concave shrinking and surface tension will keep the edges apart. If the glaze cracks during the drying or early firing periods, the water content and shrinkage should be reduced by introducing calcined zinc oxide or china clay. A weak, brittle underslip can sometimes be improved by increasing the English ball clay content to aid the glaze to resist cracking. On the other hand too great a quantity of high shrinking clay material will cause some underslips to crack. The character of the plastic clay is very important. Irregular patches of crowfooting on glazed or vitrified slip surfaces may be caused by finishing a surface after it has dried too much. Such patches of cracked slip are commonly noticed on mitered ware, patched ware or those in which cracks have been repaired after pressing and partial drying. In most of these, the clay has dried too far to finish without producing tearing stresses in the surface. Considerable glaze cracking troubles can be caused by variations in body composition, pressing and finishing.

c) Glaze Peeling Although synonymous in some writings with shivering, we limit peeling to the separation of the glaze, or underslip and glaze, from the body when the surface of the body is not broken. Soluble salts may form a coating on the surface during drying and prevent the underslip from adhering or the underslip may be so designed that it will not cling well to the body because of too high drying or firing shrinkage, or insufficient vitrification. The soluble salts can be eliminated by the use of barium compounds. An increase in English ball clay or fluxes will tighten the slip but on the other hand some of the tightest slips (vit slips tightened with fluxes) give the most trouble with glaze peeling. It may be necessary to reduce the thickness of the underslip to a minimum (a single light coating) for, the thicker the coating, the easier will be the separation. Glazes may be tested for adhesion or tendency to peel by tapping lightly with a chisel. If it is necessary to dig out portions of the body with particles of glaze, the adhesion is good. A glaze may be removed from a body by tearing through a soft, weak underslip. A disrupting stress, caused by differences in expansion and

[1] *Jour. Amer. Ceram. Soc.*, **1**, 537 (1918).

contraction of the body and glaze may act through the underslip. A glaze applied directly to the body surface does not peel in the above sense but may shiver.

d) Crazing Crazing is a cracking of the glaze after solidification on cooling, caused by excessive tension. The cracks may lie (1) only in the upper surface of the glaze, (2) throughout the thickness of the glaze or (3) may continue into the body and weaken it. The most common types of crazing show a map effect in which most of the lines intersect at right angles. Parallel lines and other designs may also be found. It is a very common phenomenon developed in thin, brittle coatings which shrink more than the foundation or base material. Examples: The rich cement surface of concrete floors, some bituminous road materials, paints, and fused or melted coatings.

e) Shivering A separation of the glaze from the body when portions of the body are removed with the broken pieces of glaze. This is the result of a superior compressive strength of the glaze compared to a weaker tensile strength of the body. It usually occurs at the edges, corners or raised ornamental edges where the compressive forces of the glaze are concentrated and the resistance of the body is the lowest. In this sense, shivering cannot be caused by a layer of soluble salts between the glaze and the body. With an underslip, a glaze can shiver only when the slip is so thin that the glaze has eaten through it into the body or when the slip is of the fusible type and has intimately tied itself by fusion into the body surface.

4. Factors in the Study of Crazing and Shivering

Crazing and shivering are considered to be the results of opposite stresses. With the glaze under tension, the stress will be relieved by glaze cracks or crazing. When the glaze is under compression because the contraction from the temperature of solidification in the kiln has been greater than that of the body, relief occurs by a tearing of both glaze and body at the exposed edges. A large portion of crazing takes place in the initial cooling of the kiln. Delayed crazing is usually caused by subsequent rapid changes in temperature or thermal shock, after the ware is in use.

1. Relative Coefficient of Expansion and Contraction Between Body and Glaze This relationship can be varied by changes in composition of either glaze and body. Relative coefficients can be roughly calculated from the coefficient factors of the individual members, given in the following table by Staley. The combined coefficient of a mixture is the sum of the products of each member's coefficient factor times its percentage by weight in the mixture. While these factors may apply to the melted and fused glazes and enamels, they do not apply to the body calculations where only partial fusion has developed and a large portion of the quartz has not been changed to silica glass with a low coefficient factor of 0.8 but retains a very high one. However, the table is of value in changing the coefficient of a glaze for the same body.

If a glaze crazes the glaze coefficient is too large and some of the members having high factors should be partially replaced with members having lower factors. (See Table IX.) The remedy for shivering is the reverse. Make the glaze smaller when cold by introducing more alkali, lime and lead at the expense of silica, magnesia, boric acid and zinc oxide. Hence a high silica content as fused silica or silica glass in the glaze will tend to cause shivering and high quartz in the body (partially changed to cristobalite during the firing) will make a rotten, punky structure which will magnify either a crazing or shivering tendency, but usually shivering. Undoubtedly other factors are important in the glaze-fit problem. We have used glazes of the same calculated coefficient on the given body and yet with all other conditions the same the results have been widely different. Hence, other properties peculiar to the individual components must oftentimes overbalance the coefficient of expansion.

TABLE VIII

FACTORS FOR MELTED WEIGHTS AND COMPARATIVE COEFFICIENT OF EXPANSION[1]

Chemical	Factor for Melted Weight	Factor for Coeff. of Expansion
Alumina	1.0	5.0
Antimony trioxide	1.0	3.6
Barium carbonate	0.777	2.33
Barium oxide	1.00	3.00
Borax	0.53	1.66
Boric acid	0.565	0.0565
Boric oxide	1.0	0.1
Calcium carbonate	0.56	2.8
Calcium oxide	1.0	5.0
Chromium oxide	1.0	5.1
Cobalt tetroxide	0.933	4.1 (black)
Cobalt monoxide	1.0	4.4 (light brown)
Copper oxide	1.0	2.2 (black)
Cryolite	1.0	7.4
Ferric oxide	1.0	4.0
Flint	1.0	0.8
Fluorspar	1.0	2.5
Kaolin	0.86	2.44
Red lead	0.98	4.1
Yellow lead	1.0	4.2 (litharge)
Magnesium carbonate	0.48	0.05
Magnesium oxide	1.0	0.1
Manganese dioxide	0.9	2.0
Manganese monoxide	1.0	2.2
Nickel trioxide	0.9	3.6 (black)
Nickel monoxide	1.0	4.0 (green)
Potassium carbonate	0.68	5.8 (calcined)
Potassium nitrate	0.466	4.76
Potassium oxide	1.0	8.5
Rutile	1.0	4.1
Silica	1.0	0.8
Soda ash	0.58	5.8
Sodium antimonate	1.0	4.64
Sodium carbonate	0.216	2.16 (crystalline)
Sodium nitrate	0.365	3.65
Sodium oxide	1.0	10.00
Tin oxide	1.0	2.00
Titanium oxide	1.0	4.1
White lead	0.86	3.6
Zinc oxide	1.0	2.1
Zinc carbonate	0.65	1.36

Feldspar, clays and other natural and variable materials should be analyzed and the relative coefficient calculated from the oxide content. The above factors cannot be used to calculate the true thermal expansion of silicate fusions but only to give the

[1] Scott, Mayer & Havas.

relative effect of the different ingredients in enamels, glazes and glasses. For instance, the correct individual factor for silica is 0.15 instead of 0.80.

TABLE IX

FACTORS FOR COMPARATIVE COEFFICIENTS OF EXPANSION

Sodium oxide	10.0	Antimony trioxide	3.6
Potassium oxide	8.5	Barium oxide	3.0
Chromium oxide	5.1	Kaolin	2.44
Alumina	5.0	Copper monoxide	2.2
Lime	5.0	Zinc oxide	2.1
Cobalt monoxide	4.4	Tin oxide	2.0
Lead monoxide	4.2	Manganese dioxide	2.0
Titanium oxide	4.1	Borax	1.66
Ferric oxide	4.0	Silica glass	0.8
Nickel monoxide	4.0	Boric oxide	0.1
		Magnesia	0.1

An example of the coefficient of expansion calculation with two commercial terra cotta glazes is given below. Glaze A has a greater tendency to craze than glaze B. The high lime content was partially replaced by barium and magnesium carbonates and the clay and feldspar contents reduced.

Glaze A			Glaze B		
Flint	0.056×0.8	0.0448	Flint	0.089×0.8	0.0712
Feldspar	0.516×2.8	1.4448	Feldspar	0.480×2.8	1.3440
Whiting	0.188×2.8	0.5264	Whiting	0.106×2.8	0.2968
Zinc oxide	0.086×2.1	0.1806	Zinc oxide	0.075×2.1	0.1575
Clay	0.154×2.44	0.3758	Clay	0.120×2.44	0.2928
			Barium carbonate	0.064×2.33	0.1491
Coeff. Factor		2.5724	Magnesium carb.	0.016×0.05	0.0008
			Tin oxide	0.50 ×2.00	0.1000
			Coeff. Factor		2.4122

Staley[1] states that it takes a variation of 0.03 units to give an enamel an appreciable change.

2. Thickness of Glaze The thicker the glaze, the greater the tendency to craze. The strains caused by temperature differences in separating layers of the ordinary glasses of rather high coefficient of expansion are not relieved fast enough by thermal conductivity. Thin glassware or thin glazes will stand thermal shock better than the thicker ones.

3. Glaze Attack on Body At the surface of the body a very thin film of glaze has dissolved enough of the body ingredients to equalize the strains. The effect of the body compositions becomes less in the outer layers. The attack varies with the time and temperature of firing. Underfired glazes more readily craze than well-matured glazes. An underfired body develops crazing very easily, probably due to the lack of change and solution of the quartz particles in the body and in single fired bodies to the lack of tieing-in of the glaze by solution. When an underslip is placed on the body, the glaze can attack the upper surface only of the slip unless this coating is very thin. However, practice would indicate that owing to the comparative thinness of this coating as compared to that of the body, the underslip transmits stresses between the two in a very

[1] "The Feldspar Problem in Enamel Making," *N. J. Ceramist*, May, 1924, p. 95.

able fashion. Hence the relationships between body and glaze must still be studied even though an intervening layer of underslip is present.

4. Elasticity of the Glaze and Body Undoubtedly, the more elastic a glaze, the better it would be able to withstand strains of expansion or contraction. Some of the relative component factors of the coefficient of elasticity given by Jena Glass (p. 189) are as follows:

Silica	0.1533	MnO	0.3460
Alumina	0.1750	BaO	0.3560
Magnesia	0.2500	K_2O	0.3969
PbO	0.2760	CaO	0.4163
B_2O_3	0.2840	Na_2O	0.4310

Glass can be compressed without rupture to a greater degree than it can be stretched. It can also be twisted or subjected to a shearing stress to a greater degree than when in compression or tension.

The modulus of elasticity in tension is	6×10^{11}
The modulus of elasticity in compression is	4×10^{11}
The modulus of elasticity in shear is	2×10^{11} (Duff)

The moduli are the reciprocals of the coefficients of extensibility, compressibility and shearing.

5. Relative Strength of Body and Glaze Littleton[1] gives lead and borosilicate glass a tensile strength varying from 12 to 15 kilograms per sq. millimeter. This is 17,000 to 21,000 pounds per square inch tensile and indicates from 102 to 126,000 pounds per square inch compressive strength. The compressive strength of terra cotta cubes may be taken as 6,000 pounds per square inch or from 1000 to 1300 pounds per square inch tensile strength. Riddle and Laird[2] give the tensile strength of a spark plug porcelain body alone as 8890 pounds per square inch. From the strength of the glass given above, a rough calculation can be made of the strength of the glazed body:

Tensile strength of body alone, 0.4 in. diam., 0.12566 square in., 1117 pounds. $\frac{1}{64}$ inch of glaze adds an area of 0.02038 square inch which at 17,000 pounds per square inch adds a strength of 346 pounds, and at 21,000 pounds per square inch adds a strength of 428 pounds.

1463 pounds divided by 0.146 sq. in. (total) equals 10,020 lbs. per sq. in.

1543 pounds divided by 0.146 sq. in. (total) equals 10,570 lbs. per sq. in.

These values are similar to those obtained by Riddle and Laird when a good glaze was added to the test pieces and the calculation gives a general check of Littleton's results on glasses of a different composition. However, if the glazes crazed, the cracks apparently extended into the body and brought the tensile strength down to 3,000-4,000 pounds per square inch.

a) Relative Strengths A glaze coating varying from $\frac{1}{64}$ to $\frac{1}{32}$ of an inch will develop a compressive strength of from 1600 to 4000 pounds. This is working against a total tensile force of from 1000 to 13,000 pounds in the one inch of body. However, a glaze under tension can only develop 266 to 655 pounds while one inch of body in compression can hold back with 6000 pounds. The glaze has the advantage when it is compressed, but the disadvantage when in tension.

---

[1] J. T. Littleton, Jr., "Tensile Strength of Glass," *Phys. Rev.* (1923). *Ceram. Abs.*, **3** [3], 70 (1924).

[2] F. H. Riddle and J. S. Laird, *Jour. Amer. Ceram. Soc.*, **5**, 500 (1922).

6. Is the Glaze under Tension or Compression? That a number of wall tile, pottery and terra cotta glazes are under compression when first drawn from the kiln is shown by the examples of thin, free members glazed on one side only, which are bowed with the glazed side convex. If this stress were magnified or the body not as strong, shivering would result. When both sides are glazed the piece is straight. This could be used as a test of new glazes or new ingredients in both bodies and glazes to see if a sufficient change had been made in the relative coefficient of expansion to indicate a tendency for crazing or shivering. During the original cooling of the ware in the kiln, some glazes may become rigid and possess a higher strength while the body is yet soft and deformable or the reverse may be the case. Hence the relative difference in temperature of solidification may have a bearing on this bowing phenomenon.

7. Relief of Stress Glazes like glasses are but semi-rigid liquids, which if given time at room temperatures will flow or yield to stress. This yield becomes easier as the temperature is raised. Hence, if glazes are cooled very slowly after they have stiffened they will have a better chance to adjust themselves to the body than if cooled fast. Likewise rapid thermal changes after the initial cooling will be accompanied by stress and oftentimes by rupture. Bernard Moore[1] believed that most pottery glazes were under compression after the initial cooling. The glaze then adjusted itself to the body on standing and equilibrium was established. However, if the original difference has been too great, the body had the opportunity of placing the glaze under tension and crazing often resulted when the ware was reheated in the decorating kiln. If the glaze had remained in its original state of compressed stress it would have gone back to equilibrium during the reheating and probably not have continued into the state of tensile stress and crazing. It was shown that the crazing took place during the reheating, for some glazes in which this occurred showed partially fused edges of the craze cracks. According to this theory, a piece may show both crazing and shivering; shivering during the original cooling and crazing on reheating.

8. Thermal Conductivity and Faster Heating and Cooling of the Glaze than the Body The surface of a body receives the heat and transmits it to the interior. The time of transmission varies as the conductivity and the distance. Stress between the glazed surface and the interior will vary with the thickness and the porosity of the body. A quenching test caused worse crazing on the inside of large earthenware cups than on the outside, probably because of the fact that the heating came from the bottom and the outside glaze and body were heated and expanded before the interior surface was affected. The latter was thus placed under a severe tension. The back portion of terra cotta in the wall is maintained at a more uniform temperature than the glazed surface which is heated more quickly in the morning sun and cooled more quickly at night. If heated first, the glaze will be placed under compression. In most cases this does not cause shivering, but when it is chilled suddenly it will crack from the sudden unequal contraction. The porous semi-fire clay terra cotta body is a poor conductor of heat.

9. Dunting and Crazing Dunting is a form of body cracking or body crazing caused by thermal changes, lack of sufficient elasticity or proper annealing of the body. It is common with bodies of high silica content or any which are too hard, brittle or glass-like. The body cracks in most cases extend in long parallel lines through the glazed surfaces from one side to the other. Badly dunted china ware will fall apart in large sections when struck. Thus some of our glaze cracks may not originate in a defective glaze but in a defective body which would crack under the same

[1] Bernard Moore, *Trans. Ceram. Soc.* (Eng.), **12**, 331 (1912-13).

conditions without a glaze coating. A test could be devised to determine the dunting of the body and its effect on the glaze by running spalling tests of the usual transverse strength specimens of body and determine the decrease in strength. An exceptionally elastic glaze would be needed to adhere without cracking to these bodies of poor spalling resistance.

6. Vitrified Slip Coatings. (Standard Finish or Vit Slips)

These were probably the original coatings on architectural terra cotta and were made at first of tight, red or buff firing clays to correspond with red and buff brick work. The texture is that of brick work or tooled stone. When the light grays, creams or even white vitrified coatings were desired, the terra cotta chemist adopted a veneering of a whiteware body whose vitrification point was lowered to his temperatures by increased amounts of feldspar or by the addition of other fluxes. Such mixtures are similar to vitrified floor tile bodies and both should be non-absorbent when tested with red India ink.

Examples:

	Cones 2-3*	Frit			Cones 6-7
Feldspar	28.0	75.0	Red lead	Flint	19.6
Flint	23.0	25.0	Flint	Cornwall stone	44.2
Cornwall stone	10.0	———		China clay	24.4
Frit	4.5	100.0		Ball clay	11.8
Ball clay	21.0				———
Georgia kaolin	12.0				100.0
Borax	1.5				
	———				
	100.0				

*P. G. Larkin, "The Production of Underglaze Colors by Use of Soluble Salts," *Jour. Amer. Ceram. Soc.*, **1**, 429 (1922).

Considerable difficulty is often experienced in coating a coarse grogged body with a vit slip. Fine crowfoot-like cracks will form across the exposed grog grains during shrinkage in drying and firing. These may not be apparent without close inspection when drawn from the kiln but can be made readily visible by washing the surface with muddy water, which duplicates the dirt accumulation after the piece has been placed in the building wall.

The selection of the ball clay is very important for vitreous slips. The English ball clay with its tough, elastic plasticity and low vitrification temperature is very good for this class of coatings. Some grades of ball clay will produce ink-proof coatings by themselves when fired to cones 6-7. Fluxes like white mica and asbestos have given good indications in vitrified coatings for producing tight slips and could be used in emergency cases to prevent cracking because of the shape of their particles.[1] It is difficult to get the iron-free micas or magnesium silicates in cheap commercial quantities. Too great an addition of fluxes like the feldspar or the low temperature fluxes like lead, the borates or the alkalis, produce fused or glazed slips in the hotter parts of the kiln. Crazing can also be expected near the glazing condition.

G. Color Work

Since one of the important claims for architectural terra cotta is that it can be produced in an infinite variety of colors and that most any color scheme of the architect

can be developed, the terra cotta chemist must have sufficient skill and resourcefulness to make these claims good. A large part of the terra cotta jobs must be delivered in 30 to 60 days and unless the chemist has a large variety of proved colors in his files he often has but a single firing test in which to duplicate several chosen colors. He should also be prepared to make very similar colors in gloss glazes, matt glazes and vit slips. The difficulty lies in the fact that the same minerals or stains give different shades of the same color and in some cases different colors in glazes and slip of different compositions. No color, texture, glaze composition or new batch of any ingredient should be left to chance without a trial through a large kiln in the usual firing procedure. The unusual is constantly appearing. A well stocked filing cabinet of a large variety of colors is a great source of satisfaction to the chemist, and gives him greater assurance that quick matchings can be made accurately, without placing his company at a disadvantage with the architect.

The most common shades are the lighter ones, such as variations near that of pure white, creams and grays, which take the smallest amounts of usually the cheapest coloring ingredients. The most common exception to this is the opaque white which usually calls for about 5.0% of tin oxide at about 60 cents per pound.

I. Common Colors

1. White Very few people demand a pure white and no one gets it. Various brands and different shipments of tin oxide give various tones and the buff or brown color of the body or underslip cannot be entirely masked. The old whiteware pottery scheme of adding a faint cobalt blue tinge to a "white" glaze, to give a blue or green "white" instead of the more easily noticed cream "white" is commonly done by the addition of about 0.015% cobalt sulphate ground directly with the glaze in the mill. The sulphate can be changed to the insoluble carbonate by the use of soda ash.

Matt glazes by their internal crystallization (or undissolved grains) prevent direct transmission of light rays from the underslip or body and hence give a "white" opacity which gloss glazes do not have. And many "white" orders have been turned out with no tin oxide in the glaze or slip coating. However, the effect of variations in the thickness of spraying can be modified by the addition of a little tin oxide as "insurance" in the glaze coat. If the underslip is thin, the darker color of the body may often give a blue gray tone to the "white" glaze. The tin therefore aids greatly in the maintenance of uniformity.

The latest theory in regard to the production of opacity by tin oxide is that it is not due to undissolved particles suspended in the liquid silicate, but due to the production of independent droplets of liquids having high indices of refraction in comparison to the glass in which they are suspended. Thin sections under the microscope are transparent.

The cheaper substitutes for tin oxide such as sodium metantimonate (leukonin or substitute), sodium-zirconium silicate compounds (terrar) are not satisfactory at the high temperatures. The use of spinels is still in the experimental stage. The former, together with the oxides or other compounds of zirconium, titanium, antimony, arsenic, fluorides, etc., are used to replace tin oxide in low temperature work such as enamels for metals.

a) Pink Discolorations Care should be taken in adding tin oxide to a high lime glaze to give it opacity or whiteness. This lime-tin oxide combination with low zinc oxide will give a pink color which is strong enough to spoil a white job. It can be easily avoided by raising the zinc oxide at the expense of the lime. The chrome-tin pink colors contain high lime.

2. Creams. a) Iron Dilute iron oxide either as purified Fe_2O_3 or as red firing clays (Albany slip or even some local surface clays) are commonly used

up to cones 4-5. Iron oxide or silicate holds its color better in the high clay bodies, underslips or vit slips at the high temperatures (cones 6-7) than it does in glazes. In the latter, slight variations in the kiln atmosphere cause wide fluctuations in color. The dissociation pressure of Fe_2O_3 reaches the partial pressure of the oxygen in the atmosphere (152 mm of mercury) at 1350°C theoretically, but this temperature can be reduced by the presence of associated compounds in the glaze and slight changes in the oxygen content of the kiln gases. Iron colors in the glaze can be aided by iron colors in the underslip.

b) Rutile For more stable and yellower creams, it is better to use rutile, uranium or antimony creams. Iron free rutile, varying from 0-3% will give straw colored creams which increase in intensity to a maximum but which does not deepen with further additions. Large amounts harden or wrinkle the surface. Brown tones are often found and the shades vary with the glaze composition.

c) Uranium Commercial uranium oxide is a mixture of oxides, sodium uranate, sodium uranyl carbonate and ammonium uranate. One sample contained 81.09% U_3O_8 and 1.27 U_2O_5. Up to about 1.5% it gives clear or brownish creams but beyond that the green shades appear in a very irregular fashion. Portions of the salt are soluble and this probably accounts for the mottling effects produced when the commercial oxide is added raw. It would be better to add it as an insoluble calcined stain. Low zinc oxide glazes are best for the yellow shades of uranium.

d) Antimony Antimony is added as a stain prepared from a mixture of lead, clay, tin oxide, lime and sodium nitrate. However, it is like iron oxide for it vaporizes fast at the high temperatures. Small kilns will give yellower creams than the larger kilns. One or 2% of the oxide diluted in a stain will give a good cream. Example of antimony stain:

White lead	22.6	Tin oxide	14.4
Antimony oxide	20.2	Whiting	11.2
China clay	15.8	Sodium nitrate	15.8
			100.0

Variations can be secured by adding small quantities of manganese dioxide or traces of chromium oxide, etc. to give brown or gray tones to the above creams.

3. Grays A pure gray is a mixture of white and black. The best grays for glaze work should then be made by adding a black stain to a white glaze. However, although some stains may give almost a true black when concentrated, they will give blue, brown or green shades when diluted and the predominating color factor is revealed. A true gray glaze is very hard to produce. Manganese dioxide when added to clay slips retains its blackness and produces good grays but when dissolved to a manganese silicate in a glaze, it turns brown. Hence most of the gray glazes are brown grays, cream grays or even grays with pink tones. The latter can be produced by adding a small amount of chrome-tin-pink stain to the glaze. Iron chromate is hard to dissolve and has been used for grays with brown and even purplish tones. A hard fired black stain is the best method of approach for a true gray. But it will be necessary to carefully balance the blue of cobalt, the browns of manganese, nickel and iron, and the green of chromium to keep one of these shades from predominating when dilute.

4. Tan and Browns These will be encountered when experimenting with the grays. One-half per cent chromium oxide in a zinc glaze will give a tan color. The better shades are more often produced in matt glazes than in the gloss. Manganese varied with the cream producing materials is reliable for most of the shades included under this heading. Nickel gives peculiar and variable shades of brown. It cannot be relied upon as a predominating color but is used as a secondary ingredient,

especially in the darker colors. Under certain conditions it will give a nickel green, a nickel violet or purple.[1]

II. Polychrome Colors

The above colors represent the most widely used shades in large units or masses. They can be varied with manganese spots, granite and pulsichrome mixtures, but the general tone is usually light.

Under polychrome colors we list the brighter and darker colors for use in small units either with the above simple colors or with brickwork and other masonry.

1. Blue No other ingredient takes the place of cobalt. It is a very intense coloring agent, can be obtained in the insoluble or soluble forms, but because of its high strength must be carefully watched to prevent blue spots occurring in places where not wanted. Formerly for the lighter shades, it was necessary to dilute the cobalt oxide by calcination with silica, plus clay or zinc oxide, but now it can be bought on the market in such a finely divided form that no spots are noted even when diluted in a white glaze. For very faint blue colors the soluble sulphate or nitrate can be used. These can be precipitated in the glaze after thorough mixing by the use of soda ash. Most of the colors produced in ceramic work are such mixtures of colors that it is difficult to properly define them. However, cobalt blues are the nearest approach to a true primary color, and cobalt gives blue shading into black on concentration with practically all compositions and under most all conditions. Pink tones have been noted at several times.

2. Greens Copper or chromium alone under the proper conditions will give green shades. Nickel is also in this class but is unreliable from a commercial standpoint. The other method of producing a green is that commonly used in paints, *i.e.*, to mix a blue and yellow. The cobalt blue colors are pure enough but the yellows from rutile, antimony, uranium and iron are not pure and a brownish green is usually produced. Uranium is probably the best to use for the purest shade of green.[2] As the content is increased in a clear or white glaze it shades into dirty yellow-greens. The addition of cobalt combines with the yellow to form a green which is assisted by the natural green from the uranium itself. The mottling effects of the variable commercial uranium oxide can be overcome by the use of a soluble form of cobalt, by pre-calcination as a stain or by the use of rutile.

Two or 3% copper oxide gives good greens, especially when darkened slightly with cobalt oxide, but it is a low temperature color and fades rapidly above cones 3-4. The high temperature uranium-cobalt greens give the nearest approach to the copper-green which has long been a standard for low temperature pottery work.

Chromium oxide works well at both high and low temperatures. It is hard to get into solution and is better used after dilution and pre-calcination as a stain. Three to 4% is about the maximum quantity which can be introduced for its refractory qualities harden the glaze. Zinc oxide tends to change a chromium green to a tan or brown. As ZnO is next to feldspar in fluxing power for the glazes of the cone 4 to 6 type, the high temperature chromium green zincless glazes are usually harder than the other glazes in the kiln and special precautions need to be taken to insure a sufficient temperature to develop them. While chromium oxide is refractory and difficultly soluble, yet it gives trouble from vaporization when fired in the same kiln with either lighter colored zinc or tin oxide glazes. With the former, adjoining surfaces will be stained brown and with the latter a pink color. This makes it difficult to use in polychrome work with other light

[1] See F. K. Pence, *Trans. Amer. Ceram. Soc.*, **14**, 143 (1912).

[2] H. Wilson, "A Cobalt Uranium Green Glaze for Terra Cotta," *Jour. Amer. Ceram. Soc.*, **1**, 238 (1918).

colors on the same piece of ware. The chromium greens have a yellow tone and at the high temperatures do not match the copper low temperature greens even when darkened with cobalt. The best substitute at high temperatures for the copper greens is the uranium-cobalt mixtures, which develop their best color in zinc oxide glazes. Seger's Victoria green stain or Stull's cobalt-chromium green are two of the best chromium green stains. The latter is far more easily prepared and gives a deeper green tone.

Victoria Green[1]		Stull No. 14[2]	
$K_2Cr_2O_7$	36	Cr_2O_3	128
Fused $CaCl_2$	12	CoO	1
Silica	20	Flint	43
Marble	20	Borax	4
CaF_2	12		100
	100		

3. Pink For rose or pink colors, the chrome-tin-lime combination is the most commonly used. In the absence of zinc oxide, or if the latter is low, tin added to a high lime glaze will produce a faint pink.[3] Two chrome-tin-lime stains are as follows:

	A	B	
Tin oxide	50	40	
Whiting	28	26	
Flint	20	31	
Potassium dichromate	2	3	chromate of lead
	100	100	

In any stain where a soluble ingredient as potassium dichromate is used, it is well to dissolve it in just enough water to temper the remainder to a plastic mass. Then dry before calcining. In this way the small amount of soluble dichromate is scattered in the finely divided molecular form throughout the mass. The excess passes with the water to the surface but is later recovered after calcination by fine grinding. If the chrome-tin-lime stain shows a green color after calcination, it is well to wash it with water to remove the free chromium salts. Some advise a second calcination after washing.

As ZnO attacks the pink of the $CaO\text{-}SnO_2$ it might be expected to hurt the chrome-tin-lime rose colors. This largely depends on the composition of the glaze and if trouble is found, raise the lime and lower the zinc oxide. Good pinks have been made on a commercial scale with a matt glaze containing 8.6% ZnO but the lime content was 18.8%.

4. Blacks As in water colors, blacks are made by mixing several dark colors, avoiding an excess of any which will give blue, brown or green tones. The following can be tried:

Iron chromate	52
Nickel oxide	18
Cobalt oxide	7
Chromium oxide	7
Red lead	16
	100

[1] Seger's, "Collected Writings," **2,** 662.

[2] R. T. Stull, "Clayworking Problems," *Brick and Clay Rec.*, p. 67.

[3] E. C. Hill, "Terra Cotta Glazes," *Trans. Amer. Ceram. Soc.*, **17,** 381 (1915).

D. F. Albery, "Pink Discolorations of a Terra Cotta Glaze," *Trans. Amer. Ceram. Soc.*, **14,** 640 (1912).

The lead starts the reaction during calcination. If the stain is too hard for efficient grinding, lower the lead content. For other modifications substitute manganese dioxide for the more expensive nickel oxide and ferric oxide for the iron chromate. Some of the best black glazes are those placed over a red or other dark body. In this way they are not diluted by a lighter colored background showing through the black coating.[1]

5. Low Temperature Brilliant Colors for Polychrome Decoration

When bright reds, deeper than the chrome-tin-lime rose shades, deep yellows, etc., are desired, the chemist must often resort to a second firing at low temperature and the use of the prepared overglaze colors from such chemical dealers as the Roessler and Hasslacher Chemical Company or the Drakenfeld Chemical Company of New York. Great varieties of the brilliant shades have been developed and are widely used for pottery decoration. These prepared powders are mixed with water or oils and can be sprayed or painted on the required fired surface of either matt or gloss glaze, and are then fired to temperatures near cone 015. Gold, silver and platinum colors can also be obtained in this manner. The second firing to these irregular temperatures with often but a small number of pieces is expensive and breaks into the routine schedule and should be avoided whenever possible. When terra cotta is refired in small kilns, the large pieces are often dunted or crazed from the quick heating and cooling. A better oxidizing atmosphere is obtained at these low temperatures by firing with wood than with coal. Compositions and methods of mixing and using these low temperature colors can be found in R. Hainbach's book on pottery decorating.[2]

III. Granite Finishes

The first coatings called "granites" were made by blunging coarse manganese dioxide into the slip or glaze after grinding. When larger spots were desired, black spots were applied to the surface after spraying by spotting on a black stain which had been finely ground in water or in a clay slip. Such spots are mechanical in appearance; they are either round when they strike the surface perpendicularly or long and streaked if they strike at an angle.

Natural granite rock shows irregular black spots. Some are clearly exposed on the surface while others show but faintly through the translucent masses of quartz or feldspar crystals. The spots therefore vary considerably in shape, regularity and intensity. Far better imitation of the natural granite is made by partially hiding a black coating with an irregular white or gray coating.

For a glazed granite finish, imitating polished granite, a black underslip is applied first and then partially covered by spotting a white underslip until the background shows only in small irregular spots. A glaze coating sprayed over this combined underslip coating gives the glaze or glossy polish. The natural stone effect is largely derived from the variation in the thickness of the white spotted coat. The thin portions will be translucent and allow the black background to be partially seen. The shape and size of the spots will have a natural irregular shape and size. Tin oxide can be used in the spotted coatings if greater opacity is desired.

A spray gun with lowered air pressure, an enlarged slip tube, or changed relative positions of the air and slip pipes can be made to throw spots instead of breaking the slip into a fine mist.

For vit slip granites, to imitate rough stonework, the colors are added to vit slips instead of the underslips and the glaze coating is omitted. Black stains which will show black in vit slips will often have a different complexion under a glaze. A few clays on the market fire black and can be used to aid in producing black slips.

---

[1] Seger's "Collected Writings," **2**, 651, for various underglaze colored stains.

[2] "Pottery Decorating," D. Van Nostrand Co., New York. Chaps. 7 to 13.

Intermediate spottings of different colored spots or varied colored slips can be made for different granite effects. At the present time a pinkish "Texi-granite" effect is much desired. The slips used in partially hiding a darker background should be of high viscosity so that the spots will not flow together and obliterate the openings altogether. The water content can be reduced by the use of an alkali like soda ash or sodium silicate.

IV. Pulsichrome Applications

The granite fad led to color combinations and textures never seen in natural stones. Various colored glazes or slips were applied at the same time or so near the same time that their aqueous suspensions blended before drying. Major Gates of the American Terra Cotta Co., invented a machine for the simultaneous application of several colored slips or glazes. By the use of a small motor, pressure is applied to the slip in several flexible rubber hoses by small arms or fingers which alternately spurt the slip out in large droplets. A series of small holes surrounding the slip openings allow the compressed air to act merely as a carrier of these droplets to the terra cotta surface. The different colored drops or slugs of a glaze strike the surface and while wet mingle incompletely, producing a mottled or streaked surface. Several other guns without the mechanical propulsion have been used since Mr. Gates' pulsichrometer was placed on the market to throw several colors simultaneously.[1]

V. Polychrome Decoration

If the different colors of a polychrome order occur on separate pieces of terra cotta, no trouble is experienced in the method of application. However, if two or more colors are to be applied to the same piece, the difficulties increase not only in keeping them separated during the application but also from discolorations caused by vaporization in the kilns, in such cases as chromium, zinc and tin oxides. A number of methods have been devised for polychrome application; and the best method must be determined from (1) the size of the colored areas, (2) the number of colors or colored areas on the same piece, (3) the shape and finish of the outline of the colored areas and (4) the respective colors to be applied. The methods in use are:

1. Painting Colored Glazes with the Brush This is slow and may show streaking due to variation in thickness and brush marks. Glazes of the viscous Bristol type do not heal well in the kiln. The method is adapted to glazes of low viscosity and to small areas.

2. Spraying Colored Glazes Using Masques A plaster, paper or metal shield protects certain portions of the surface while colored glazes are applied to other portions. This is suitable for large areas, especially in repeating designs.

3. Single Fire Overglaze Polychrome Work A single glaze is sprayed over the whole surface and the insoluble overglaze colorant is applied by a fine spray gun over the desired portions and brushed off when dry from the other portions. It is best to add 2-3% of gum arabic to the glaze so that it can be brushed and treated roughly when dry. This overglaze is simply one of the colored stains finely ground. The glaze on fusion attacks the stain from beneath and forms a concentrated colored layer on the upper surface. Great care must be taken to apply just the proper quantity to provide the desired color. An excess of stain remains as undissolved powder on the surface. This method can be improved by applying fluxed

[1] L. M. Munshaw, "Pulsichrometer vs. Old Method of Applying Glazes, *Jour. Amer. Ceram. Soc.*, **5**, 827 (1922). Also, Ernest Clark, "The Use of Pulsichrome from the Manufacturer's Standpoint," *Ibid.*, p. 826.

colors or colored glazes. It was found that the brighter colors of yellow and rose could thus be obtained when the glaze had less of a chance to dissolve and attack the stain particles. The method has been used for a long time in shading the background of raised designs on pottery.[1]

4. Painting with Soluble Metallic Salts

Most of the color producing metallic compounds can be secured in some soluble form. These salts are blended in water solutions and painted with glycerine as a carrier to the dried glaze or vit slip surface. Acid salts which attack the glaze can be neutralized with alkali. It is another case of addition of the color only to the areas desired. The variety of colors which have been produced in this way are described by H. Wilson and P. G. Larkin.[2,3] The range is limited to simple colors which can be produced by blending the colors in the glaze itself. In other words, the glaze is given a chance to attack them separately. In the calcined oxide stains, a greater variety of colors can be produced because combinations can be secured in the pre-calcination which remain undissociated in the glaze, while when added separately in the oxide or as soluble salts they do not have a chance to combine before the glaze dissolves them.

H. Kilns and Firing

I. Kiln Construction

Both periodic and railroad tunnel kilns of the muffle type are now used for firing. The periodic muffle kilns are round and vary from one or two tons (monkey or test kilns) to 100 tons in capacity. A forty- or fifty-ton kiln is the most useful size for the average plant. The Northwestern Terra Cotta Co., of Chicago, have been operating a Dressler tunnel kiln for a number of years with success.

Gas, coal and oil are used as fuel. The muffle walls of the periodic kilns are usually 4½ inches thick but with gas a 2¼-inch wall has been used. Several of the lower courses next to the hot fire boxes are often thickened to add life to the lining at this point.

1. Flue Arrangements

A number of systems of travel of the combustion gases around the muffle have been devised. The simplest types are the best both for uniformity of distribution of the gases and for longer life.

a) The gases rise from the fire boxes through vertical flues, reverse in the crown and descend through separate flues between the fire boxes, converge under the floor to the center and rise through a center stack.

b) The gases rise from the fire boxes through vertical flues, pass over the crown and descend through the outer shell of a center stack, radiate under the floor, turn down at the circumference to a lower set of flues, converge again to the center and rise through the middle of the center stack. (Northwestern type.)

c) The gases rise from the fire box, pass over the crown and down through a single center stack, radiate to the circumference under the floor and pass up vertical flues between the fire boxes to the top section of the double crown and out the center stack, which in this case is not connected with the stack in the interior. (Steiger type.)

d) The old up-draft type (Conkling-Armstrong) where the gases partially circulate under the floor directly from the fire box or pass directly up a staggered flue system in the wall to a center crown hole and thence out into one of the old type pottery stacks. The bottom may be colder than the top.

---

[1] H. Wilson, "Overglaze Colors at Cones 6-7," *Trans. Amer. Ceram. Soc.*, **19**, 653 (1917).

[2] L. M. Munshaw, "Pulsichrometer vs. Old Method of Applying Glazes," *Jour. Amer. Ceram. Soc.*, **5**, 827 (1922). Also Ernest Clark, "The Use of Pulsichrome from the Manufacturer's Standpoint," *Ibid.*, p. 826.

[3] H. Wilson, "Polychrome Decoration of Terra Cotta with Soluble Metallic Salts," *Jour. Amer. Ceram. Soc.*, **1**, 353 (1918). P. G. Larkin, "Note on Colors Produced by the Use of Soluble Metallic Salts," *Ibid.*, **1**, 429 (1918).

Essential Points (1) A vertical rise of the hot gases as soon as they pass from the fire boxes, (2) at least one passage of the gases through a center stack and (3) at least one passage of the gases under the floor. The third type given above, having three crowns is not as preferable as the other two with lighter crown loads. Both of the first two have given very uniform firings for many years. A modification of No. 2 or the Northwestern type with a single center stack is found in several plants. The gases after collecting at the center in the lower flues pass through another flue to an outside stack which may serve several kilns. A high grade of fire brick is needed in the fire boxes. With a coal-fired kiln whose muffle interior reaches cones 6-7, cone 20 will be brought down in the back end of the fire box. Oil flames develop even higher local temperatures. All underground flues should be kept dry.

2. Fire Boxes The horizontal is the most common type of grate bar, although the open inclined grate bar is also used with success. In the latter case the fires are closed by additions of coal alone.

The Underwood producer gas system was tried at the Northwestern plant but no direct savings in fuel were noted. The producer gas gave somewhat better control, less kiln expense and reduced the smoke nuisance.[1]

Forced draft has been used to advantage at the Denver Terra Cotta Company.[2] The use of lower grade coal, better control, cheaper labor and a net saving of 20% in firing costs is reported. See the Boss system for firing brick.

II. Setting

Terra cotta is not set very high in the kilns. Not over two averaged sized pieces or three small ones can be placed on each other because of warping. Glazed surfaces must not touch. Therefore in order to fill the kiln, three to six decks are built with clay stands and large square tile braced against the center stack and the walls. A terra cotta kiln containing 80 tons of terra cotta will need 24.5 tons of kiln furniture. Sand, grog and clay bobbers may be used between pieces for bedding and even distribution of load. Large pieces are set at an angle of 30° on large tile so that gravity will assist in preventing cracking during the shrinking period.

III. Firing Terra Cotta Kilns

Only a few hours of water-smoking is necessary for these buff firing, highly grogged bodies. The weight of raw clay per cubic foot of kiln space is small when compared to brick setting and the terra cotta in most cases can be heated as fast as the draft can be started and the large mass of kiln walls, furniture and muffle walls can absorb and transmit the heat. Steam jets are often used in the stack as an injector to start the draft in the complicated flue system. The steam holes connecting the interior of the muffle with the outside are left open until the vapor escape has ceased. After that the heating-up period is rapid and if the muffle is tight there is not much danger of spoiling the ware by reducing conditions. If the ware is flashed at the beginning of a firing, the discoloration can often be removed by slow oxidizing heat. If the flame breaks through the wall at the finishing temperature the ware will stay flashed.

---

[1] F. B. Ortman, "Producer Gas in Periodic Muffle Kilns," *Jour. Amer. Ceram. Soc.*, **4**, 669, (1921).

[2] J. L. Carruthers, "Use of Forced Draft for Terra Cotta Kilns," *Jour. Amer. Ceram. Soc.*, **5**, 449 (1922), and *Bull. Amer. Ceram. Soc.*, **1**, 222 (1922).

For most glazes the kiln must be uniform in temperature to produce uniform results of color, texture of glaze work and uniform degree of vitrification of vit slip coatings. Small kilns will give glossier results than the larger and slower cooling ones. Small kilns are apparently fired to a higher temperature even when the cones are identical, and it is the practice on some yards to fire their smaller kilns to lower cones to obtain results which match the product from the larger kilns.

Those clays which contain pyrite or other sulphur bearing minerals (such found near the Chicago district) should have ample ventilation between the red heat and vitrified or partial fusion periods of the glaze; otherwise the sulphur gases will be entrapped only to come out later when the glaze is fluid. This causes trouble with blistering, scumming and discolorations.[1] Such troubles are not noticed with the clays which mature at the high temperatures and only with the low temperature glazes containing frit or lead.

Uniformity within the kiln is established by soaking at the finish and it is surprising how evenly a kiln will adjust itself after having been brought up to the finishing temperature in a most irregular fashion. With the large amount of highly heated muffle wall it is very easy to overheat the ware by carrying the heavy firing to the finishing cone, which should be "soaked-down" rather than "fired-down." In some plants the fires are allowed to burn down until the back wall shows black or the kiln will overheat. In others, the fires are pulled at the finish and immediately sealed.

IV. Cooling and Dunting

Dunting cracks are very fine, hair-like cracks which extend from the slip or glaze coating down into the body itself, a form of body crazing. They are caused by the inability of the body to withstand changes of temperature, involving the expansion or contraction of the piece either in the cooling of the kiln or later in the building. The cracks are more liable to occur on large units of heavy construction and cross-section than on the smaller lighter pieces. When the cracks appear in the building wall they are more often found on ware exposed on all sides than on those set into the wall proper. The sides of a building exposed to the direct hot rays of the sun (southern and western) will be cracked worse than the shaded sides, which are not heated to as high a temperature as the others.

Fire cracks may be produced in all bodies by rapid cooling and if cooled slowly enough most bodies are free, temporarily at least, from fire cracking. We have taken the regular terra cotta body from a small kiln while red hot in the interior. The ware showed a number of wide open cracks around the edges just as if the outside had shrunk too fast for the hot expanded interior and had to give way. However, on cooling, these cracks closed so tightly that we could not find them without the aid of dirty water. In a great many cases of delayed dunting and also of crazing, and slip cracking the cracks were developed in the kiln but were not noticed until after the ware had been placed in the building and coated with soot and street dirt. Other bodies, glazes and slips will be under strain when drawn from the kiln and the strain will relieve itself by cracking after a few heatings in the sun and coolings at night or in the winter time.

V. Composition and Dunting

The hard dense bodies are more sensitive to fire cracks than the open porous ones. In general the bodies containing free quartz either present in the clays or added in the non-plastic or grog content will give way more easily than the non-siliceous bodies. However, the character of the clay itself exerts considerable influence in resistance to the disrupting volume changes of the free quartz and the quartz content cannot always be

[1] F. B. Ortman, "Composition of Kiln Gases and the Effect on Glazes," *Jour. Amer. Ceram. Soc.*, **3**, 476 (1920).

accepted as a criterion on the dunting question. Dunting is not always inversely proportional to the absorption or porosity of the body though the general relations hold true. One of the best remedies is to increase the coarseness of the grog. Clays having the ability to bond grog grains without shrinking excessively between the grains and forming minute internal cracks should withstand dunting strains the best.

Siliceous bodies are sensitive in the red heat temperatures. The largest change in volume of the silica minerals occurs when β cristobalite inverts to α cristobalite between 220-275°C. If the quartz remains as quartz, after heating a large volume change takes place near 575°C. Consequently siliceous bodies must withstand a greater rate of contraction after they have become rigid and brittle.[1]

The following table gives some recent firing costs and time data collected from terra cotta kilns in the Pacific Northwest.

TABLE X

PACIFIC NORTHWEST CLAYWORKERS' ASSOCIATION
TERRA COTTA MUFFLE KILN DATA

	1	2	3	April, 1, 1924 4
Size muffle, diameter	18′ 6″	14′ 6″	16′ 2″	16′ 10″
Height at center	13′ (?)	10′ 1¼″	15′ 8″	13′ 0″
Capacity in tons	25-35	12-18	24	19-20
Number fire boxes	10	7	8	7
Flue system, reverse in	Crown	Crown	Bottom	Bottom
Total gate area, sq. ft.	47.5	26.5	——	65
Location of stack	Center	Center	Center	Center flue Outside stack
Hours setting	——	——	20	16
Hours water-smoking	40	30	48	48-54
Hours heating up	44	40	——	40-50
Hours soaking	2	2	——	8-10
Total hours firing	86	72	116	105
Hours cooling	168	120	120	144-168
Maximum temperature	1260°C	1260°C	1160°C	1200°C
Type pyrometer	Brown	Brown	Thwing	Bristol
Highest cone down	6	6	5	4-6
Cost per hour kiln labor	$ 0.62	$ 0.62	$0.60	$ 0.60
Total cost labor per kiln plus supervision	46.50	38.50	——	67.76
Cost labor per ton ware	1.55	2.60	——	3.39
Per cent No. 1 ware	100	100	98	99-100
Type Fuel	Coal	Coal	Coal	Coal Wood (water-smoking)
Fuel cost per ton fuel	$6.00	$6.00	$6.85	$8.87

[1] E. C. Hill, "Fire Cracking of Terra Cotta," *Jour. Amer. Ceram. Soc.* **5**, 299 (1922); *Bull.* **1**, 235 (1922).

Fuel cost delivered to kiln	6.50	6.50	7.00	9.30
Tons fuel used per kiln	24	14	——	14 coal 5.4 cords wood
Pounds fuel per ton ware	1600	1865	2400	1480
Cost of fuel per ton ware	5.20	6.10	8.40	8.28

Another Pacific Coast terra cotta company gave the following figures for their 1923 average:

2.4 barrels of oil per ton terra cotta, costing $3.36 per ton terra cotta fired to cone 4 in 85-90 hours with oil at $1.40 per barrel.

I. Fitting Department

Several orders are going through the shop at the same time. Hence as each kiln is drawn, the ware for the various jobs is sorted and piled separately in the fitting room. As soon as enough of any section of an order accumulates it is laid out on the floor just as it will appear in the building. A certain amount of adjusting in position will help mask variations in color, dimensions and slight warpage. Defective pieces are eliminated. Overall dimensions of the different sections are measured with the proper jointing. When necessary, straight edges are produced by grinding either on the older type rubbing bed or on the later vertical carborundum grinding wheel machines (Besly grinders) which have appeared recently for terra cotta and refractory shape grinding. The rubbing bed is a large horizontally revolving steel table on which wet sand grinds the lower surface of the piece as it is held in position by hand. Air hammers and hammer and chisel are used for cutting or removing larger portions, special backing braces, etc. When the fitting shop foreman is satisfied with a given section each piece is marked on the side with the setting number in black paint for identification and location at the job.

Small holes or broken corners are patched with the quick setting magnesia or zinc oxychloride cements colored to match the glaze, slip or body as the case may be. These produce rough dirt catching surfaces, show up shortly after the building is completed and therefore cannot be used extensively. Examples:

Patching cement Mix calcined zinc oxide into a paste with a 1.82 solution of zinc chloride. Barium or magnesium chlorides may be used to partially replace the zinc chloride. For retarders use borax or dilute the zinc oxide with an inert powder such as marble dust. The zinc chloride may be prepared by dissolving zinc metal scraps from the profile bench in commercial hydrochloric acid.

Shipping is done by truck, railroad car or boat. The ware is packed in straw and pieces must not touch. In cars, wooden bracing is used to prevent all movement. For exporting all ware must be crated.

J. Terra Cotta in the Wall

The two worst natural enemies of building materials are the sun and frost. The wall of terra cotta, brick, stone or concrete which is exposed to the direct rays of the sun is usually found to be in a worse condition than the shaded exposures on the north or east side of the building. A damp climate with an occasional freezing spell, even though the temperature never reaches zero, causes more disintegration of structural materials than a dry one where the temperature range is extreme in both summer and winter. Hard, dense, brittle bodies are troubled more by the sun while freezing water catches the low fired, weak and porous ware. The influence of the sun may be accessory to the effect of freezing, in that it merely increases the number of freezings and thawings. The warm southern cities have far less trouble than the colder and more variable northern cities.

No very conclusive data has been obtained by which the weathering properties of a terra cotta body can be estimated from such data as absorption, strength, hardness or porosity. The following factors, however, are of importance to the life of the terra cotta in the wall.

I. Elasticity

The elasticity of the body and glaze or the ability to give and take with pressure, strains and thermal volume changes. The modulus of elasticity of the terra cotta body is near 3,500,000 pounds. This equals the stress in pounds per square inch divided by the deformation in inches per inch per square inch.

II. Thermal Coefficient of Expansion

The thermal coefficient of expansion and contraction of the body and glaze; their separate magnitudes and relative coefficients. For the body the value is 0.0000049 per degree F. A peculiar defect called circular spalling has been noted in different parts of the country and even in as mild a climate as Seattle. It is found on rounded surfaces such as the cheek of a baluster exposed to the afternoon sun. A few cracks are first noticed in the glaze in the most exposed position. These increase, assume a circular form and finally a circular spall with a cone shaped portion of the body falls out. It is probably due to a local concentration of temperature on the exposed cheek as it occurs only on that portion receiving the perpendicular rays of the sun. It is more likely to occur with tight, or highly siliceous bodies and is probably magnified by repeated freezings and thawings during freezing weather which is accompanied by bright sunshine.

III. Thermal Conductivity

A body having a greater thermal conductivity will be stressed less when heat is applied to one side only as is the case of terra cotta in the wall. A more porous body will have less thermal conductivity but on the other hand should be able to adjust itself to internal volume changes under pressure more easily.

IV. Porosity and Absorption

This is the amount of pore space in terms of the volume or weight. Not only the magnitude of the pore space but also the character of the voids, as shown by the rate of absorption, is important. The average absorption is near 14.0% in a range of 8.00 to 22.0%.

V. Crystallization of Water and Salts

Disintegration action of the crystallization of water and soluble salts. Most of the lime and cement joints are porous enough to offset any advantages of glazed or vitrified terra cotta coatings. Special protection should be given in many places by sheathing, flashing and water-proof cements. The relation between resistance to water freezing and the per cent water absorption is still an open question. Apparently the size of the pore space is an important factor and it is claimed that the small pore space is worse than the larger. H. D. Foster,[1] after testing hollow building tile at the Bureau of Standards, believes that an absorption of 16% apparently marks a very definite line in the resistance of tile to freezing and thawing.

VI. Strength of Body

Over-pieces of terra cotta jobs average near 8,000 pounds per square inch with a range of from 13,500 to 3,500 pounds per square inch. A minimum modulus of rupture (transverse strength) of 1500 pounds per square inch is suggested.

[1] "Strength, Absorption, and Freezing Resistance of Hollow Building Tile," *Jour. Amer. Ceram. Soc.*, **7**, 189 (1924).

VII. Variations of Strength when Wet and Dry

Most materials are weaker when saturated but some show greater strengths.

VIII. Effect of Concentrated Loads

A great many failures of terra cotta in the wall are engineering defects. The settlement of buildings will produce concentrated stresses which often exceed the strength of all the non-metallic building materials. Rusticated ashlars are often sheared by these loads unless specially reinforced.

IX. Jointing

Hard cement joints will transmit strains and often raised joints such as are found on sill courses will be sheared due to the unequal distribution of the strain. Elastic and expansion joints are often necessary, especially on sun exposed balustrades.

X. Concrete

Terra cotta manufacturers are almost unanimous in the opinions that a concrete building causes more trouble with the terra cotta facing than does a steel building. They also object to the filling of terra cotta with concrete. Volume changes occur in concrete from a variation in water content If a concrete beam or panel is held rigid at the end or sides by steel framework, even the original shrinkage on drying will cause it to crack, and it expands and contracts with each subsequent wetting and drying. Concrete block is the only type of masonry construction which gives a distinct separation crack in the vertical joints between the mortar and the block. This is due to the shrinkage of the blocks after setting. Dirt and mortar flakes fall into these cracks and prevent the complete return of the block to fill the crack. Consequently a continuous horizontal expansion takes place with time and subsequent soakings. It has been observed that monolithic concrete itself increases 0.14% in length in 2.5 years.

It is difficult to reproduce failures of individual pieces by filling them with concrete and subjecting them to alternate wettings and dryings. However, this is not exactly the same condition as that of a terra cotta wall of considerable dimensions where the expansion is cumulative and apt to be concentrated on a few pieces. It is customary to fill the terra cotta backs with brick and mortar. The reason given for this is that the bearing resistance is increased. However, this weight in itself increases the load on the terra cotta and also the backs cannot be filled to the top while setting. Consequently there is an added load with very little additional support. It is not necessary to fill the spaces with anything. The terra cotta facing if properly designed carries but a small load, even in a tall building, for almost every floor is individually supported by steel shelves or angle irons projecting from the main steel skeleton.

Department of Ceramic Engineering,
University of Washington,
Seattle, Wash.

TERRA COTTA BIBLIOGRAPHY

By Hewitt Wilson

(Assisted by Members of the Ceramic Classes of the Ohio State University and the University of Washington)

I. Clays

1. H. Ries, "Clays, Occurrence, Properties and Uses," pp. 216-19, Wiley and Sons, Pub.

2. L. Behrendt, "Mining of Indiana Clay for Terra Cotta," *Bull. Amer. Ceram. Soc.*, **3** [9], 331 (1924).

3. T. A. Klinefelter, "Clay Preparation," *Jour. Amer. Ceram. Soc.*, **7** [7], 509 (1924).

4. E. C. Hill, "The Effect of Some Fluxes in the Absorption and Transverse Strength of a Terra Cotta Body," *Jour. Amer. Ceram. Soc.*, **5** [11], 832 (1922).

II. Grog

5. S. Geijsbeek, "Notes on the Action of Grog in Ceramic Bodies," *Trans. Amer. Ceram. Soc.*, **7**, 133 (1905).

6. C. B. Harrop, "Method of Calcining Clay for Grog," *Trans. Amer. Ceram. Soc.*, **18**, 165 (1916).

7. C. E. Fulton and R. J. Montgomery, "The Effect of Grog on a Fire Clay Body," *Trans. Amer. Ceram. Soc.*, **17**, 410 (1915).

8. F. A. Kirkpatrick, The Effect of Size of Grog in Fire Clay Bodies," *Trans. Amer. Ceram. Soc.*, **19**, 268 (1917).

9. R. H. Minton, "The Use of Furnace Slag as Grog," *Jour. Amer. Ceram. Soc.*, **1**, 185 (1918).

10. R. L. Clare and D. F. Albery, The Effect of Variation of Size of Grog," *Jour. Amer. Ceram. Soc.*, **3**, 384 (1920).

11. H. E. Davis, "The Effect of the Size of the Grog Grain," *Jour. Amer. Ceram. Soc.*, **3**, 641 (1920).

12. B. S. Radcliffe, "Terra Cotta Body Investigation," *Jour. Amer. Ceram. Soc.*, **7** [11], 834 (1924).

13. P. G. Larkin and E. R. Curry, "Notes on Terra Cotta Body Shrinkage," *Jour. Amer. Ceram. Soc.*, **8**, 113 (1925).

III. Water

14. "The Influence of Varying Water Content in a Fire Clay Mixture," *Trans. Amer. Ceram. Soc.*, **17**, 437 (1915).

IV. Soluble Salts and Barium Compounds

15. J. W. Mellor, "The Determination of the Amount of Soluble Salts in Clays," The Pottery Industry, **1**, 53.

16. M. E. Gates, "Using Barium Hydrate in Terra Cotta Bodies," *Jour. Amer. Ceram. Soc.*, **3**, 313 (1920).

17. C. W. Parmelee, "Soluble Salts and Clay Wares," *Jour. Amer. Ceram. Soc.*, **5** [8], 538 (1922).

18. W. L. Howat and G. A. Williams, "Testing Barium Carbonate for Use in Terra Cotta Bodies," *Bull. Amer. Ceram. Soc.*, **2** [6], 161 (1923).

19. Other references: See **XI. Pinholing and Peeling.**

a) E. M. Lovejoy, "The Use of Barium Compounds in Preventing Scum," *Trans. Amer. Ceram. Soc.*, **8**, 255 (1906).

b) Ries, Univ. Texas *Bull.*, **102**, p. 45.

c) Grimsley and Grout, West Va., *Geol. Surv.*, **3**, p. 45.

d) Parmelee and Moore, *Trans. Amer. Ceram. Soc.*, **11**, 467 (1909).

e) H. Ries, Clays, Occurrence, Properties and Uses, p. 116.

f) H. F. Staley, *Trans. Amer. Ceram. Soc.*, **17**, 200 (1915).

g) Barringer, *Trans. Amer. Ceram. Soc.*, **4**, 224 (1902).

h) J. W. Mellor, Quantitative Inorganic Analysis, p. 630.

i) Grout, West Va., *Geol. Surv.*, **3**, 26 (1905).

j) Ries, New Jersey, *Geol. Surv.* ,**6**, 76 (1905).

k) Ashley, Bur. Stands., *Tech, Paper*, **23**, p. 96.

l) A. V. Bleininger, "Electrical Conductivity of Clays," *Trans. Amer. Ceram. Soc.*, **15**, 523 (1913).

m) W. E. Emley and S. E. Young, "The Production, Manufacture and Use of Compounds of Barium," *Trans. Amer. Ceram. Soc.*, **17**, 240 (1915).

V. Mold Making and Calcined Gypsum

20., R. B. Keeler, "Recent Improvements in Mold Making," *Trans. Amer. Ceram. Soc.*, **19**, 585 (1917).

21. Additional references:

a) George Simcoe, "Data on Plaster Molds," *Trans. Amer. Ceram. Soc.*, **9**, 187 (1907).

b) H. E. Ashley, "The Testing of Plaster of Paris," *Trans. Amer. Ceram. Soc.*, **9**, 59 (1907).

c) H. E. Ashley, "Pottery Plaster," *Trans. Amer. Ceram. Soc.* **10**, 76 (1908).

d) F. B. Allen, "Transverse Test Applied to Pottery Plaster," *Trans. Amer. Ceram. Soc.*, **16**, 98 (1914).

e) H. Hope, "Plaster Pail Washing Apparatus," *Trans. Amer. Ceram. Soc.*, **16**, 240 (1914).

f) G. A. Williams, "Notes on Manufacture of Plaster Molds," *Trans. Amer. Ceram. Soc.*, **17**, 323 (1915).

g) C. H. Kerr and R. J. Montgomery, "The Influence of Variations in Water Additions, Lime Addition and Temperature in the Setting of Plaster of Paris," *Trans. Amer. Ceram. Soc.*, **18**, 180 (1916).

h) R. J. Montgomery and C. H. Kerr, "Methods for the Factory Testing of Plaster of Paris," *Trans. Amer. Ceram. Soc.*, **18**, 188 (1916).

i) W. E. Emley, "Measurement of Time of Set of Calcined Gypsum," *Trans. Amer. Ceram. Soc.*, **19**, 573 (1917).

j) T. A. Klinefelter and F. C. Parsons, "Shop Notes on Plaster Shop," *Jour. Amer. Ceram. Soc.*, **6** [7], 183 (1923).

k) T. A. Klinefelter and F. C. Parsons, "Short Cuts in Miter Cutting," *Jour. Amer. Ceram. Soc.*, **6** [7], 786 (1923).

VI. Aging

22. R. L. Clare and R. N. Long, "The Value of Aging a Terra Cotta Body," *Jour. Amer. Ceram. Soc.*, **4**, 458 (1921).

23. Additional references:

a) E. McK. Ogle, "Unweathered vs. Weathered Clay," *Trans. Amer. Ceram. Soc.*, **3**, 173, 176, 179 (1901).

b) E. C. Stover, "Bacterial Growth as a Factor in Aging Clay Mixtures," *Trans. Amer. Ceram. Soc.*, **4**, 183 (1902).

c) E. C. Stover, "Bacteria in Clay Mixtures," *Trans. Amer. Ceram. Soc.*, **5**, 358 (1903).

d) E. G. Acheson, "Egyptianized Clay and Discussion," *Trans. Amer. Ceram. Soc.*, **6**, 51, 55, 56, 63, 77 (1904).

e) L. H. Minton, "An Investigation of the E. G. Acheson Process for Toughening Clays," *Trans. Amer. Ceram. Soc.*, **6**, 249 (1904).

f) Thomas Gray, "Can Water from the Clay Press be Re-used," *Trans. Amer. Ceram. Soc.*, **11**, 365 (1909).

g) H. E. Ashley, "The Colloid Content of Clay and Its Measurement," *Trans. Amer. Ceram. Soc.*, **11**, 539 (1909).

h) H. Spurrier, "The 'Why' of Aging Clay," *Jour. Amer. Ceram. Soc.*, **4**, 113 (1921).

VII. Pressing, Molding and Finishing

24. R. F. Geller, "Possibilities of Terra Cotta Casting," *Jour. Amer. Ceram. Soc.*, **4**, 883 (1921).

25. H. E. Davis, "Viscosity of Indiana Clay Slip with Electrolytes in Regard to the Casting of Terra Cotta," *Jour. Amer. Ceram. Soc.*, **5** [10], 702 (1922).

26. John Clark, "Pressing Terra Cotta," *Jour. Amer. Ceram. Soc.*, **5** [9], 623 (1922).

27. Klinefelter and Parsons, "Good and Bad Practice in the Pressing Department," *Jour. Amer. Ceram. Soc.*, **5** [9], 623 (1922).

28. Major E. Gates, "Machine for Making Terra Cotta Blocks," U. S. Pat. 1,482,646 (1924).

VIII. Drying

29. E. D. Gates, "Humidity System of Drying," *Trans. Amer. Ceram. Soc.*, **11**, 375 (1909).

30. W. J. Stephani, "Drying Terra Cotta Bodies," *Trans. Amer. Ceram. Soc.*, **13**, 746 (1911).

31. E. M. Lovejoy, "Discussion of Terra Cotta Driers," *Jour. Amer. Ceram. Soc.*, **1**, 667 (1918).

32. F. B. Ortman and H. E. Davis, "Humidity System of Drying Terra Cotta," *Jour. Amer. Ceram. Soc.*, **4**, 796 (1921).

33. A. E. Stacey, Jr., and H. B. Matzen, "Ceramic Drying and Driers," *Jour. Amer Ceram. Soc.*, **8**, 525 (1925).

IX. Underslip and Vitrified Slip Coatings

34. S. L. Geijsbeek, "Stoneware Slips and Engobes," *Trans. Amer. Ceram. Soc.*, **4**, 48 (1902).

35. R. T. Stull, "Manufacture of Enamel Brick and Enamel Brick Slips," *Trans. Amer. Ceram. Soc.*, **12**, 711 (1910).

36. H. R. Griffin. Clay, Glazes and Enamels, Chaps. 6, 7, 8, 9.

37. J. W. Mellor. Studies of Clay Slips, Collected Papers, Pottery Industry, **1**, p. 88.

38. Hewitt Wilson, "Terra Cotta Slips. The Use of Asbestos and Chlorite Mica," *Jour. Amer. Ceram. Soc.*, **3**, 114 (1920).

39. H. E. Davis and J. S. Lathrop, "A Study of Slips for Standard Finish Terra Cotta," *Jour. Amer. Ceram. Soc.*, **8** [1], 23 (1925).

X. Glazes, General

40. L. E. Barringer, "Making Enameled Brick," *Trans. Amer. Ceram. Soc.*, **5**, 256 (1903).

41. C. W. Parmelee, "Terra Cotta Glazes," *Trans. Amer. Ceram. Soc.*, **9**, 577 (1907).

42. C. W. Parmelee and R. Heidingsfeld, "Note on Terra Cotta Glazes," *Trans. Amer. Ceram. Soc.*, **14,** 844 (1912).

43. E. C. Hill, "Terra Cotta Glazes," *Trans. Amer. Ceram. Soc.*, **17,** 381 (1915).

44. R. B. Keeler, "Influence of Variable Silica and Alumina," *Trans. Amer. Ceram. Soc.*, **18,** 282 (1916).

45. F. A. Kirkpatrick, H. C. Arnold, and C. F. Geiger, "An Attempt to Fit Enamels to a Plastic Clay Body," *Trans. Amer. Ceram. Soc.*, **18,** 139 (1916).

46. E. C. Hill, "Glaze Composition and Glazing," *Jour. Amer. Ceram. Soc.*, **4,** 25 (1921).

47. A. S. Watts, "Specifications for Commercial Feldspar and Flint," *Jour. Amer. Ceram. Soc.*, **3,** 722 (1920).

48. R. H. Minton, "Development of Shivering," *Trans. Amer. Ceram. Soc.*, **17,** 130 (1915).

49. J. L. Carruthers, "Shivering of Terra Cotta," *Jour. Amer. Ceram. Soc.*, **5,** 518 (1922).

50. F. H. Riddle and J. S. Laird, "Control of Glaze Fit by Means of Tensile Strength Specimens," *Jour. Amer. Ceram. Soc.*, **5,** 500 (1922).

51. J. E. Hansen, "A Modification of the Empirical Formula in Glaze and Enamel Calculations," *Jour. Amer. Ceram. Soc.*, **5,** 338 (1922); *Bull. Amer. Ceram. Soc.*, **1** [10], 235 (1922).

52. Also see:

a) H. H. Sortwell, "Earthenware Bodies and Glazes," *Jour. Amer. Ceram. Soc.*, **4,** 990 (1921).

b) G. Blumenthal, Jr., "Note on Hardness of Glazes," *Jour. Amer. Ceram. Soc.*, **4,** 896 (1921).

c) C. F. Binns, "The Development of the 'Matt' Glaze," *Trans. Amer. Ceram. Soc.*, **5,** 50 (1903).

d) R. C. Purdy, "Matt Glazes," *Trans. Amer. Ceram. Soc.*, **14,** 671 (1912).

e) F. K. Pence, "A Theory for the Cause of Mattness in Glazes," *Trans. Amer. Ceram. Soc.*, **14,** 682 (1912).

f) H. F. Staley, "The Microscopic Examination of 12 Matt Glazes," *Trans. Amer. Ceram. Soc.*, **14,** 691, 704-708 (1912).

g) F. K. Pence, "Matt Glazes," *Trans. Amer. Ceram. Soc.*, **15,** 413 (1913).

h) A. R. Heubach, "Notes on the Cause of Mattness in Glazes," *Trans. Amer. Ceram. Soc.*, **15,** 628 (1913).

i) A. P. Potts, "Notes on Matt Glazes," *Trans. Amer. Ceram. Soc.*, **15,** 628 (1913).

j) H. H. Stephenson, "The Oxygen Ratio," *Trans. Amer. Ceram. Soc.*, **13,** 612 (1911).

k) W. G. Whitford, "Study of Three Component Normative Systems in Raw Lead Glazes," *Trans. Amer. Ceram. Soc.*, **19,** 312, 316, 322 (1917).

l) H. F. Staley, "The Control of Fusibility in Fritted Glazes," *Trans. Amer. Ceram. Soc.*, **19,** 642 (1917).

m) H. F. Staley and L. C. Hewitt, "The Cost of Raw Lead Glazes," *Trans. Amer. Ceram. Soc.*, **19,** 659 (1917).

XI. Pinholing and Peeling

53. M. A. Coates, "Soluble Salts and the Behavior of Slips and Glazes," *Trans. Amer. Ceram. Soc.*, **16,** 162 (1914).

54. Hewitt Wilson, "Pinholing and Peeling of Glazes," *Trans. Amer. Ceram. Soc.*, **19,** 209 (1917).

55. See: **IV. Soluble Salts and Barium Compounds.**

XII. Pink Discolorations

56. D. F. Albery, "Pink Discolorations of a Terra Cotta Glaze," *Trans. Amer. Ceram. Soc.*, **14,** 640 (1912).

57. See: E. C. Hill, "Terra Cotta Glazes," *Trans. Amer. Ceram. Soc.*, **17,** 381 (1915). **X. Glazes, General.**

XIII. Granite Imitations

58. C. W. Parmelee and R. Heidingsfeld, "Production of Black Spots on Terra Cotta," *Trans. Amer. Ceram. Soc.*, **14,** 227 (1912).

59. R. Heidingsfeld, "Glaze Imitation of Granite," *Trans. Amer. Ceram. Soc.*, **14,** 245 (1912).

XIV. Polychrome and Colors

60. H. A. Plusch, "Polychrome Decoration," *Trans. Amer. Ceram. Soc.*, **9,** 473 (1907).

61. Hewitt Wilson, "Overglaze Colors at Cones 6-7," *Trans. Amer. Ceram. Soc.*, **19,** 653 (1917).

62. G. D. Phillips, "Terra Cotta Bodies, Slips and Glazes," *Trans. Amer. Ceram. Soc.*, **16,** 169 (1914).

63. F. H. Rhead, "Painting in Underglaze Colors on the Biscuit," *Jour. Amer. Ceram. Soc.*, **5** [6], 376 (1922).

64. F. H. Rhead, "Types of Glazes Suitable for Decorative Inlay Processes," *Jour. Amer. Ceram. Soc.*, **5** [5], 259 (1922).

65. F. H. Rhead, "The Italian Majolica Process and Painting Over Tin Enamels," *Bull. Amer. Ceram. Soc.*, **1** [9], 177 (1922).

66. Ernest Clark, "The Use of Pulsichrome from a Manufacturer's Standpoint," *Jour. Amer. Ceram. Soc.*, **5** [11], 826 (1922).

67. L. M. Munshaw, "Pulsichrometer vs. Old Method of Applying Glazes," *Jour. Amer. Ceram. Soc.*, **5** [11], 827 (1922).

68. Hewitt Wilson, "A Cobalt Uranium Green Glaze for Terra Cotta," *Jour. Amer. Ceram. Soc.*, **1,** 238 (1918).

69. Hewitt Wilson, "Polychrome Decoration of Terra Cotta with Soluble Metallic Salts," *Jour. Amer. Ceram. Soc.*, **1,** 353 (1918).

70. P. G. Larkin, "Note on Colors Produced by the Use of Soluble Metallic Salts," *Jour. Amer. Ceram. Soc.*, **1,** 429 (1918).

71. F. A. H. Schepers, "The Pulsichrometer," *Bull. Amer. Ceram. Soc.*, **3** [2], 53 (1924).

72. Robert Galbraith, "Some Data on the Pulsichrometer," *Jour. Amer. Ceram. Soc.*, **8,** 59 (1925).

XV. Kilns

73. I. L. Conkling, "Terra Cotta Kilns," *Trans. Amer. Ceram. Soc.*, **8,** 125 (1906).

74. H. P. Humphrey, "Terra Cotta Open Kilns," *Trans. Amer. Ceram. Soc.*, **9,** 661 (1907).

75. J. B. Millar, "Muffle Kiln for Enamel Brick," *Trans. Amer. Ceram. Soc.*, **9,** 675 (1907).

76. W. J. Stephani, "Note on the Muffle Terra Cotta Kiln," *Trans. Amer. Ceram. Soc.*, **9,** 681 (1907).

77. A. F. Hottinger, "Data on the Northwestern Terra Cotta Kiln," *Trans. Amer. Ceram. Soc.*, **9,** 684 (1907).

78. Drawings of a Terra Cotta Kiln at Steiger Terra Cotta Co., *Trans. Amer Ceram. Soc.*, **9,** 691, 692 (1907).

79. F. B. Allen, "Better Terra Cotta Slabs," *Jour. Amer. Ceram. Soc.*, **8,** 101 (1925).

XVI. Firing

80. F. B. Ortman, "Application of Producer Gas to Periodic Muffle Kilns," *Jour. Amer. Ceram. Soc.*, **4**, 669 (1921).

81. F. B. Ortman, "Composition of Kiln Gases and the Effect on Glazes," *Jour. Amer. Ceram. Soc.*, **3**, 476 (1920).

82. E. C. Hill, "Fire Cracking of Terra Cotta," *Jour. Amer. Ceram. Soc.*, **5** [6], 299 (1922), and *Bull. Amer. Ceram. Soc.*, **1** [10], 225 (1922).

83. J. L. Carruthers, "Use of Forced Draft for Terra Cotta Kilns," *Jour. Amer. Ceram. Soc.*, **5** [7], 449 (1922) and *Bull. Amer. Ceram. Soc.*, **1** [10], 222 (1922).

XVII. Strength of Body

84. R. F. Grady, "Crushing Strength," *Trans. Amer. Ceram. Soc.*, **10**, 135 (1908).

85. R. F. Grady, "Crushing Strength," *Trans. Amer. Ceram. Soc.*, **11**, 75 (1909).

86. R. F. Grady, "Absorption vs. Crushing Strength," *Trans. Amer. Ceram. Soc.*, **12**, 90 (1910).

87. E. C. Hill, "The Effect of Some Fluxes in the Absorption and Transverse Strength of a Terra Cotta Body," *Jour. Amer. Ceram. Soc.*, **5**, 832 (1922).

XVIII. Freezing Test

88. J. C. Jones, "Hardness vs. Frost," *Trans. Amer. Ceram. Soc.*, **9**, 528 (1907).

89. J. W. Cobb, "Disintegration by Crystallization and Freezing," *Trans. Amer. Ceram. Soc.*, **11**, 65 (1909).

90. W. L. Howat, "The Effect of Saturated Sodium Sulphate Solution upon the Structure of Clay Burned to Different Temperatures," *Trans. Amer. Ceram. Soc.*, **17**, 249 (1915).

91. E. Orton, Jr., "A Comparison between the Absorption, Crushing Strength and Resistance to Artificial Freezing of Some Ohio Building Brick," *Trans. Amer. Ceram. Soc.*, **18**, 686 (1916).

92. H. F. Staley, "A Comparison between the Sodium Sulphate and Freezing Tests for Drain Tile," *Trans. Amer. Ceram. Soc.*, **18**, 642 (1916).

See the Sodium Sulphate Freezing Tests of the American Society for Testing Materials.

XIX. Fitting Department

93. R. W. Bauhahn, "Fitting Department of a Terra Cotta Plant," *Brick and Clay Rec.*, April 10, 1917.

XX. Colored Glazes

94. Ernest Mayer, "Production of Underglaze Colors," *Trans. Amer. Ceram. Soc.*, **1**, 56 (1899).

95. S. Geijsbeek, "Red Glazes at High Temperatures," *Trans. Amer. Ceram. Soc.*, **1**, 62 (1899).

96. Walter A. Hull, "Chrome Tin Pink," *Trans. Amer. Ceram. Soc.*, **4**, 230 (1902).

97. F. W. Walker, "Greens from Cupric Oxide," *Trans. Amer. Ceram. Soc.*, **4**, 287 (1902).

98. E. C. Stover, "Underglaze Colors," *Trans. Amer. Ceram. Soc.*, **5**, 115 (1903).

99. "Discussion of Chrome Tin Pink," *Trans. Amer. Ceram. Soc.*, **5**, 242-55 (1903).

100. W. A. Hull, "Chrome Tin Pink," *Trans. Amer. Ceram. Soc.*, **6**, 148 (1904).

101. F. H. Riddle, "Coloring Power of Uranium," *Trans. Amer. Ceram. Soc.*, **8**, 210 (1906).

102. A. Heubach, "Red Colors," *Trans. Amer. Ceram. Soc.*, **11**, 48 (1909).

103. Purdy and Brown, "Chrome Tin Pinks," *Trans. Amer. Ceram. Soc.*, **11**, 288 (1909).

104. A. S. Rea, "Chromium Tin Pinks," *Trans. Amer. Ceram. Soc.*, **12**, 517 (1910).

105. Millard F. Gibson, "Color Series for Matt Glazes," *Trans. Amer. Ceram. Soc.* **12**, 533 (1910).

106. Felix Singer, "Position of Boron in the Glaze Formula," *Trans. Amer. Ceram. Soc.*, **12**, 683 (1910).

107. A. S. Watts, "Notes on Chrome Alumina Colors," *Trans. Amer. Ceram. Soc.*, **13**, 301 (1911).

108. E. T. Montgomery, "A Study in Underglaze Colors with View of Determining the Most Insoluble and Non-volatile Underglaze Color Composition," *Trans. Amer. Ceram. Soc.*, **13**, 723 (1911).

109. F. H. Rhead, "Experiments on Fritted Enamel Glazes at Cones 1-3," *Trans. Amer. Ceram. Soc.*, **13**, 324 (1911).

110. Forrest K. Pence, "Colors Produced by Nickel Oxide in Ceramic Mixtures Containing Zinc," *Trans. Amer. Ceram. Soc.*, **14**, 143 (1912).

111. Ross C. Purdy, "The Influence of the Composition of the Stain in the Production of Red from Chrome Tin Pink Stains," *Trans. Amer. Ceram. Soc.*, **14**, 172 (1912).

112. A. R. Heubach, "Light Green Chromium Stains," *Trans. Amer. Ceram. Soc.*, **14**, 418 (1912).

113. R. T. Stull and G. H. Brown, "Cobalt Colors Other Than Blue," *Trans. Amer. Ceram. Soc.*, **14**, 764 (1912).

114. Forrest K. Pence, "The Effect of Zinc in Underglaze Colors Containing Chromium," *Trans. Amer. Ceram. Soc.*, **15**, 118 (1913).

115. E. T. Montgomery and C. F. Tefft, "Roofing Tile Slips and Glazes," *Trans. Amer. Ceram. Soc.*, **16**, 144 (1914).

116. B. S. Radcliffe, "Some Cobalt Uranium Colors," *Trans. Amer. Ceram. Soc.*, **16**, 209 (1914).

117. R. H. Minton, "The Effect of Variation of RO Elements upon Chromium Oxide as a Coloring Agent in a Matt Glaze," *Trans. Amer. Ceram. Soc.*, **16**, 248 (1914).

118. A. E. Williams, "Notes on the Development of the Ruby Color in Glass," *Trans. Amer. Ceram. Soc.*, **16**, 284 (1914).

119. E. T. Montgomery and I. A. Krusen, "Colored Porcelain Glazes at Cone 10," *Trans. Amer. Ceram. Soc.*, **16**, 347 (1914).

120. R. M. Howe, "The Production of Underglaze Colors by the Use of Soluble Metallic Salts," *Trans. Amer. Ceram. Soc.*, **16**, 485 (1914).

121. G. A. Bole and R. M. Howe, "The Role of Chlorides and Volatilization of Ferric Iron," *Trans. Amer. Ceram. Soc.*, **17**, 125 (1915).

122. B. S. Radcliffe and C. L. Walduck, "Chrome Tin Red Glazes between Cones 2 and 8," *Trans. Amer. Ceram. Soc.*, **17**, 278 (1915).

123. R. H. Minton, "The Influence of Some Unusual Zinc Compounds in a Chrome Green Glaze," *Trans. Amer. Ceram. Soc.*, **17**, 667 (1915).

124. R. H. Minton, "Chrome Tin Colors at Cone 9," *Trans. Amer. Ceram. Soc.*, **19**, 378 (1917).

125. W. A. Lethbridge, "Underglaze Pink," *Trans. Ceram. Soc.* (Eng.), **3**, 9 (1903-4).

126. "Pottery Printing Machines," *Trans. Ceram. Soc.* (Eng.), **1**, (1901-2).

127. "Firing of Overglaze," *Trans. Ceram. Soc.* (Eng.), **2**, 62 (1902-3).

128. J. W. Mellor, "Cobalt Blue Colors," *Trans. Ceram. Soc.* (Eng.), **6**, 88 (1906-7).

129. C. E. Ramsden, "Solubility of Metallic Oxides in Glazes," *Trans. Ceram. Soc.* (Eng.), **5** [1], 1 (1905-6).

130. C. E. Ramsden, "Solubility of Metallic Oxides in Glazes," *Trans. Ceram. Soc.* (Eng.), **7**, 21 (1907-8).

131. L. Frauchet, "Development of Copper Red in Reducing Atmosphere," *Trans. Ceram. Soc.* (Eng.), **7,** 71 (1907-8).

132. "Aventurine," *Clayworker*, p. 348, April, 1897.

133. "Coloration and Decoration of Brick," *Clayworker*, p. 145, Feb., 1899.

134. A. B. Searle. Colors for Glazes, pp. 272 and 319, June, 1909, July 1909.

135. Hainbach. Pottery Decoration. Scott Greenwood and Son (1907).

136. Seger. Collected Writings, pp. 659-67 incl.

137. C. F. Binns. The Manual of Practical Potting, pp. 96-99, 123-34, 136-78 (1901). Scott Greenwood and Son.

138. R. T. Stull, "Recipes for Enameling Black, Blue and Green," (Clay Working Problems), *Brick and Clay Rec.*, 65 (1915).

139. Mellor, "Notes on Chrome Tin and Chrome Alumina Colors," Clay and Pottery Industries, **1,** 1 (1914). Griffing and Co.

140. J. W. Mellor, "Cobalt Blue Colors," Clay and Pottery Industries, **1,** 71.

141. J. W. Mellor, "Scumming of Magazine Blue," Clay and Pottery Industries **1,** 97.

142. J. W. Mellor, "Nickel in Glaze Colors," Clay and Pottery Industries, **1,** p. 364.

143. Hollinshead, Turner and Mellor, "Cobalt and Nickel Colors," *Trans. Ceram. Soc.* (Eng.), **14,** 167 (1914-15).

144. Wicks and J. W. Mellor, "Nickel in Glaze Colors," *Trans. Ceram. Soc.* (Eng.), **13,** 61 (1913-14).

145. T. Perry, "Nickel Underglaze Colors," *Trans. Ceram. Soc.* (Eng.), **13,** 67 (1913-14).

146. C. E. Ramsden, "A Study of Chromium Red Glaze," *Trans. Ceram. Soc.* (Eng.), **12** [2], 239 (1912-13).

147. C. E. Ramsden, "Notes on Chromium Red Glaze," *Trans. Ceram. Soc.* (Eng.), **11** [1], 29 and [2], 196 (1911-12).

148. A. Lomas, "Transparent Tin Oxide Glazes," *Trans. Ceram. Soc.* (Eng.), **11,** 118 (1911-12).

149. Otto Langanese, "Kosmos Sprayer for Two or Three Colors," *Trans. Ceram. Soc.* (Eng.), **11,** 174 (1911-12).

150. J. D. Whitmer, "Nickel Oxide in Glazes," *Jour. Amer. Ceram. Soc.*, **4,** 357 (1921).

151. C. F. Binns and F. Lyttle, "A Vermilion Color from Uranium," *Jour. Amer. Ceram. Soc.*, **3,** 913 (1920).

152. A. A. Granger, "On the Nature of the Coloring Properties of Selenium Red," *Trans. Ceram. Soc.* (Eng.), **21,** 89 (1921-22).

153. W. R. Bavelay, "Cobalt and Its Uses," *Jour. Soc. Chem. Ind.*, **41,** 167R.

154. J. W. Lovibond, "On Color and Its Measurement," *Trans. Ceram. Soc.* (Eng.), **10,** 66 (1910-11).

155. F. J. Rogers and J. W. Mellor, "Notes on the Crimson Chromium Tin Glaze," *Trans. Ceram. Soc.* (Eng.), **4,** 66 (1904-05).

156. R. H. H. Jones, "Crimson Glazes," *Trans. Ceram. Soc.* (Eng.), **1,** 3 (1901-2)

157. C. F. Binns. The Potter's Craft, Chap. 14, 1910. Constable and Co.

XXI. Miscellaneous

158. W. J. Stephani, "Construction and Operation of a Terra Cotta Plant," *Trans. Amer. Ceram. Soc.*, **9,** 506 (1907).

159. Otto Hensel, "The Use of Glazed Clayware as an Architectural Decoration," *Trans. Amer. Ceram. Soc.*, **3,** 153 (1901).

160. A. Heubach, "How Architectural Terra Cotta is Made," *Brick and Clay Rec.*, Nov. 4, 1913.

161. C. T. Davis, Manufacture of Brick, Tile and Terra Cotta, pp. 58-61.

162. R. L. Clare, "Causes of Failure of Terra Cotta in the Wall," *Trans. Amer. Ceram. Soc.*, **19**, 593 (1917).

163. A. S. Watts, "A Terra Cotta Industry for Ohio," *Jour. Amer. Ceram. Soc.*, **4**, 731 (1921).

164. C. W. Hill, "Terra Cotta Problems Suggested for Discussion and Investigation," *Jour. Amer. Ceram. Soc.*, **5**, 732 (1922).

165. Gabriel Ferrand, "Ceramic Art and Architecture," *Jour. Amer. Ceram. Soc.*, **5**, 743 (1922).

166. C. W. Hill, "Notes on Green Staining," *Bull. Amer. Ceram. Soc.*, **1**, 51 and 237 (1922).

167. W. D. Gates, "The Influence of the American Ceramic Society in the Terra Cotta Industry," *Jour. Amer. Ceram. Soc.*, **6**, 231 (1923).

168. A. F. Hottinger, "Looking Backward in the Terra Cotta Field," *Jour. Amer. Ceram. Soc.*, **6**, 306 (1923).

169. Pensyl Mawby, "Scheduling in a Terra Cotta Plant," *Jour. Amer. Ceram. Soc.*, **6**, 440 (1923).

170. Felix Oswald and T. Davies Pryce. An Introduction to the Study of Terra Sigillata. Longmans, Green and Co.

171. Eckardt V. Eskesen, "Investigation of Terra Cotta Work at Bureau of Standards," *Bull. Amer. Ceram. Soc.*, **3**, 158 (1924).

172. Wm. H. Powell, "Address on Terra Cotta," *Bull. Amer. Ceram. Soc.*, **3**, 255 (1924).

173. F. S. Laurence, "Terra Cotta in Architectural Design," *Jour. Amer. Ceram. Soc.*, **8**, 79 (1925).

PRACTICAL CONSIDERATIONS REGARDING ENAMELING FURNACES[1]

By W. A. Darrah

Abstract

This paper discusses certain practical requirements which appear essential to securing best commercial results from enameling furnaces. An attempt is made to point out the means by which enameling may be developed into an industry in contrast to an art. Various types of enameling furnaces are described and their advantages and limitations pointed out. The action of enamels in the furnace is discussed. The relative advantages of various commercial fuels are considered.

General

The art of applying a vitreous material or glaze to a metal is very ancient, particularly in connection with jewelry or relatively small articles. It was noticed very early that the hard glass-like finish thus obtained was very desirable from many practical standpoints, but owing to practical difficulties in manufacture, as well as the important item of cost, the use of enameled surfaces was confined to small articles of relatively great intrinsic value. The beginning of commercial enameling, as it is now known, may really be considered to come within the

[1] Received December 17, 1925.

past fifty years and the widespread application of enameled surfaces in everyday use is a much more recent development.

Today instead of confining the activities of enameling to jewelry and relatively expensive articles, enameled surfaces are used widely for such applications as cooking utensils, sanitary ware, signs, table tops, stoves, refrigerators, tile, laboratory equipment, large containers, and furniture.

This discussion is not intended to present new or original data on such an old, and well-established industry, but is just a discussion of facts which are sometimes overlooked and the classification of certain requirements which have been found to lead to successful results. While it is intended to confine this discussion to the heat applications involved in enameling, it is necessary in order to discuss intelligently this phase of the matter to consider somewhat briefly the nature of the materials used in enameling and to consider the actions which usually take place when an enamel is heated.

Action of Enamel Under Heat

Most enamels are heterogeneous mixtures of a number of constituents each with widely different characteristics. In common, enamels are composed of borosilicates mixed with varying percentages of fluxes and color-carrying ingredients. The borosilicates, of course, form the body of the enamel while the color-carrying ingredients give it the desired appearance or its required amount of opacity. In some cases, a single material may serve in several capacities as in the case of cobalt oxide which, of course, serves both as a flux and to give a strong blue color to the enamel.

It is not proposed in this discussion to go into details of enamel compositions, but it is of interest to note that in the manufacture of the enamel various materials are usually mixed, some fritted and some unfritted, some thoroughly fused and some unfused, some ingredients substantially in solution in the fused materials and some ingredients entirely undissolved. The important factors to consider in this connection are the effects of temperature, time, and mixture on a heterogeneous combination of this nature. It is evident that continued heating will cause radical changes in the compositions of nearly all enamels. In the same way heating to too high a temperature even for relatively short periods will seriously affect most enamels and such factors as the thoroughness of mixture and the fineness of sub-division of the individual particles will markedly affect ultimate results.

Many of the conditions which are frequently described as erratic can be thoroughly understood when the nature of the mixture of enamel is kept in mind.

Obviously substances which are present partly in solution will tend to dissolve more thoroughly by continued heating or by heating at higher than normal temperatures. In the same way chemical reactions which may have been partially started in the initial fritting of the enamel have a tendency to progress further on continued heating.

Incidentally such conditions explain, in a manner, why certain enamels will radically change their appearance when overfired. Materials used to produce opaqueness such as tin oxide, zirconium oxide, zinc oxide, etc., are somewhat dissolved on continued heating, and when dissolved usually lose a portion of their opaqueness.

Without going extensively into the subject of overfiring and the related conditions, at this time, we are dealing with relatively sensitive mixtures of a considerable number of materials having widely different characteristics and subject to different actions on heating.

In addition, of course, the fact that enamels usually contain considerable amounts of silicates and oxides which radically change their appearance when heated in the presence of certain gases, multiplies the difficulties of enameling.

In general, it may be stated that the object of heating the enamels when applied to a sheet of steel or cast iron is to partially fuse the fluxing materials to obtain a firm bond with the supporting material. From the enamel standpoint it is highly desirable, in most cases, to cause the heating to take place as rapidly as possible and for as short a time as possible. In making the above statement, I am considering the fact that the nature of the supporting material, in most cases, plays an important part in regulating the permissible heating period.

Since properly prepared enamels have already been subjected to the desired chemical reactions such as fluxing, formation of solution, and admixture of coloring or other ingredients, in most cases the heating operation in the enameling furnace is designed only to unite the individual particles into a single vitreous surface strongly adhering to the supporting material.

Objectives in Commercial Enameling

It is probably unnecessary to state that the two prime objectives in commercial enameling are (1) high quality, and (2) economy (low cost). In most commercial plants the factor of large production is considered equally with high quality and economy, but since with the proper plant design, production depends mainly on size and amount of equipment, this factor will not be considered at length at this time.

General Requirements for Successful Enameling

In order to produce a high quality of enameled product, it is of course essential to properly control conditions surrounding the handling and

treatment of the material long before it is placed in the enameling furnace. While the heat conditions in the enameling furnace are of utmost importance, it is practically impossible to produce high quality work with small losses if the base material is not properly cleaned and prepared or if the enamel is not properly prepared and applied.

As in many other industrial operations, cleanliness is of utmost importance since very small traces of undesirable materials will cause a large amount of difficulty when the enamel ware reaches the furnace.

Having properly prepared the enameled material, its treatment in the furnace may easily determine whether the product is to be high in quality or the reverse, but no amount of care in the firing operation can compensate for improperly pickled materials, a poor enamel mixture or poor dipping. Incidentally it is well known that the thinner the coat of finished enamel the higher the quality of the product.

Economy (the second objective) in most commercial enameling plants depends fundamentally on operating costs which are usually based on the following items: (1) Amount of labor, (2) Losses, (3) Material costs, (4) Fuel costs, and (5) Quantity of production.

An interesting corollary from the above is that fuel costs are in most plants of secondary consideration and usually represent a relatively small percentage of the total operating costs.

It is of utmost importance to keep the percentage of loss low, and it is easily possible to have a degree of loss which will considerably exceed the total cost of fuel used in enameling. It is for these reasons that the method of applying the heat, that is to say, the type of furnace used in enameling is of the utmost importance and while a high economy of fuel consumption is possible, and should be obtained, the characteristics of a fuel are usually much more important in enameling than the cost of the fuel. This subject will be discussed in greater length later.

Assuming that the enamel has been properly prepared and placed on a clean base and thoroughly dried, the characteristics of the furnace become the determining factor in controlling the quality and the economy of the manufacturing operation. This assumes properly trained operators, equipped with the necessary mechanical aids.

Heat Requirements for Successful Enameling

While the application of heat to enameling is a relatively simple operation when understood, much mystery has attached to various phases of this operation. In discussing the subject of heat application it is pertinent to point out that heat is a form of energy and like all other forms of energy with which we are acquainted, consists of two factors one of which represents quantity and is called "entropy,"

while the other factor represents what might be called a measure of activity and is known as "temperature." The product of temperature and quantity of heat gives the amount of heat energy. It is obviously possible to have a high temperature and yet a relatively small amount of heat as in the case of an acetylene torch while on the other hand it is possible to have a large amount of heat at a relatively low temperature as illustrated in the case of a steam boiler. One of the essential problems in enameling is to transfer the required amount of heat to the article being enameled quickly and without departing from the required temperature limits.

It is a well-known fact that heat is transferred by radiation at a rate which varies approximately as the cube of the temperature difference between the hot body and the cold body. The amount of heat transferred in the given time also varies directly with the area of the hot surface and the cold surface; in other words, if one square foot of hot surface will radiate 1000 B.t.u. per hour, two square feet, under similar conditions would radiate 2000 B.t.u. per hour, Therefore, it will be apparent that we have available a means for increasing the rate of heat transfer without increasing the temperature difference.

Since in the earlier discussion it has been pointed out that time is an essential element in the application of heat in enameling it will be apparent that by controlling the amount of radiating surface we have another factor which is sometimes neglected in designing enameling furnaces.

While the materials which are usually enameled have a relatively thin surface coating there is an appreciable time lag between the instant the article is placed in the furnace and the time that it reaches the desired temperature. All materials expand on heating and the raw enamel coat previous to firing expands at a different rate from the metal which carries it. For these and other reasons it is theoretically desirable, if practical, to submit articles to be enameled to a rising temperature. The theoretical objective would be to place the article to be enameled in a relatively cool place and raise the temperature of the furnace as the enameling progresses.

In many cases, this is not practical, but on the other hand, in dealing with heavy articles or complicated shapes, such a treatment is highly desirable or else as an alternative the temperature of the enameling furnace must be lowered with a corresponding increase in the enameling time. Obviously a heating cycle which submits the articles to be enameled to a falling temperature instead of a rising temperature, is the reverse of desirable, in most cases.

Probably the foremost requirement of an enameling furnace is controllability of temperature. It is true that many enameling plants

which depend upon the skill of the operators are producing highly satisfactory work in furnaces not capable of accurate control, but it would seem that this practice is reverting from a manufacturing process to an art in which, in place of mechanically fixed conditions, human judgment is being depended upon. This does not seem to be good practice in many cases although there are undoubtedly conditions which make exceptions to this rule desirable.

In addition to maintaining a controlled temperature it follows that the temperature should be known or proper indicating or better recording instruments should be used.

Because of the presence of silicates, oxides, and other compounds which are readily affected by reducing gases, oxides of sulphur, and some products of combustion, it is highly essential that the source of heat must be clean. This may be obtained by completely muffling the products of combustion or by selection of the fuel and means of handling it. This subject will be discussed at greater length in considering some factors of furnace design.

In addition to maintaining a controlled temperature in the furnace the amount of heat must be sufficient to satisfactorily carry on the enameling operation. It is not sufficient to have a furnace which is at the required temperature, but which shows a rapid fall in temperature when the door is opened or when the work is placed in the furnace. As previously pointed out the quantity of heat represents a different factor from the temperature of the furnace. As will be shown later in consideration of furnace designs, the quantity of heat depends upon such factors as type and design of muffle, area of radiating surface and other constants.

It is hardly necessary to state that in addition to having sufficient heat and a controllable temperature, the temperature must remain constant at the desired value. It is desirable, in order to secure the most uniform manufacturing conditions, to provide equipment for automatically holding the temperature constant. This condition can, of course, be approached by manual operation and there are a number of plants in which the personnel operating the furnaces are sufficiently trained to enable them to produce a high quality of work with small loss, when depending on their own judgment of temperatures. It is the writer's feeling, however, that such a condition is not as desirable as one in which conditions are automatically maintained constant.

It is essential for economical production with small loss to maintain a uniform distribution of heat. In other words, in order to operate an enameling furnace at maximum capacity and efficiently, all portions of the furnace should be at substantially the same temperature. This refers not only to all portions of the hearth but also requires substan-

tially uniform conditions in considering the hearth, the side walls, and the top of the furnace. It is obvious that a furnace, portions of which are below the required temperature, cannot be successfully used for enameling under ordinary commercial conditions without involving heavy losses. The same is true of a furnace which shows points of too high temperature. The final result of a non-uniform heat distribution is to restrict the workable area of the furnace which means an increased investment for a given output.

Perhaps the least important factor in connection with furnace heating is the subject of cost of fuel. It is obviously desirable to maintain a low fuel operating cost, and to secure as low as possible a first cost for the equipment used. In general both of these factors are not so important as the ability to produce large quantities of high-grade ware with small losses. An analysis of the division of operating costs in the average enamel plant will usually demonstrate this condition very conclusively.

Types of Enameling Furnaces

There are many types of enameling furnaces in use both in the United States and in Europe but in general these may be classified as the intermittently fired furnace, and the continuously fired furnace. The intermittently fired furnaces represent a type in which no heat is applied while the ware is in the furnace, all heating being done by the direct combustion in the enameling chamber of the fuel between the intervals of firing.

Such a type of furnace offers the advantage of eliminating the muffle which is commonly used in many of the continuously fired furnaces, but on the other hand, usually involves a reduced capacity due to the slower speed of operation. The intermittently fired furnace also inevitably involves the characteristic of firing the ware in a falling temperature and further necessitates operating over a rather wide range of temperature instead of at a single fixed temperature as in the case of most continuously fired furnaces. It seems evident that a furnace of this type requires considerably greater skill for satisfactory operation and is likely to involve greater losses than the continuously fired type of furnace. The fuel economy of the intermittently fired furnace is fundamentally no higher than a properly designed continuously fired furnace and in many cases the fuel requirements are higher for the intermittently fired furnace.

The continuously fired furnace may be divided into the three general classes (1) unmuffled, (2) semi-muffled, and (3) fully-muffled type. The unmuffled type of furnace is used relatively infrequently as it requires a specially compounded enamel not affected by furnace gases and

usually involves considerable judgment and control on the part of the operator.

The semi-muffled furnace has been used in several instances and offers the advantage of slightly reduced first cost as compared to a fully-muffled furnace. On the other hand, the semi-muffled furnace cannot be forced and requires a considerable amount of care in operation to avoid serious losses due to the action of furnace gas on the enamel, and also due to non-uniform heat distribution. In general, it would appear that the semi-muffled furnace required greater skill on the part of the operator and therefore is not quite so nearly fool-proof as the fully-muffled type.

When properly designed and constructed the fully-muffled type of furnace would appear to offer the following advantages in the average manufacturing plant: (1) large capacity, (2) quick enameling, (3) absolute cleanliness of heat, (4) uniform heat distribution, (5) high heat capacity, (6) long life, (7) high fuel economy, and (8) small losses.

Enameling furnaces may be classified as regenerative and unregenerative, depending upon whether or not the equipment is provided to recover a portion of heat in the stack gases. In nearly all commercial plants the additional investment to recover the portion of heat in the stack gases is well justified. Such an arrangement also serves in addition to increase the efficiency of the furnace by maintaining a cleaner, more satisfactory combustion and more uniform temperature conditions within the furnace.

Many attempts have been made to produce enameling furnaces in which material travels through the furnace continuously instead of being placed in the furnace and then removed. There are some theoretical advantages to a construction of this type in handling a production of large quantities of similar articles. In many enameling plants, however, the advantages of a continuously operated furnace are more apparent than real, due to the wide variation in the character of the material to be enameled. There does not seem to be unsurmountable mechanical difficulties in constructing a continuously charged enameling furnace where plant conditions make it desirable.

Some Desirable Furnace Characteristics

The design of a furnace to secure the best all around practical results involves a consideration of many varying factors most of which are recognized, but some of which are frequently neglected.

It is essential that the furnaces be of ample size for handling the amount of work required and, in general, where the production requirements permit, a few large furnaces are more desirable than many small furnaces. On the other hand, since increased size means increased

first cost, and increased radiation losses, it is desirable to keep the furnaces as small as possible and yet turn out the required production.

It is always desirable to insulate a furnace thoroughly not only from the standpoint of fuel economy but also to maintain more comfortable working conditions in the plant and to make it possible to maintain constant temperature conditions.

The door of the enameling furnace is one of the important sources of heat loss particularly during the time that it is opened. It is, therefore, important to secure quick operation of the door, quick loading and unloading of the furnace. The door should be thoroughly insulated and make a tight seal with the door jamb to prevent heat losses.

The fuel should be burned in a reliably controlled manner and the products of combustion which carry the heat should be distributed throughout the furnace flues in such a way as to give controllable, but uniform heat distribution.

The muffled type of furnace is desirable in most cases, and where the muffle is used, it should be made of permanent durable material having a high heat conductivity.

Where the heat conductivity is sufficiently high to permit, it is desirable to use a relatively thick-walled heavy muffle. A construction of this kind serves to store heat so that enameling may be carried on with a substantially uniform or rising temperature gradient rather than with the falling temperature.

It is desirable to supply as large a heat radiating surface as possible in the muffle walls.

A recuperator is desirable both from the standpoint of economy of of operation, uniformity of operation, and control of furnace conditions.

A furnace should be constructed in such a way that it will be relatively quick in reaching the operating temperature and yet will hold its temperature for considerable periods when not in use.

Desirable Fuel Requirements

There are many considerations which influence the choice of a fuel for an enameling furnace installation. In the order of their relative importance, these may be listed approximately as follows: (1) controllability, (2) cleanliness, (3) reliability, (4) uniformity, (5) economy of operation and (6) economy of first cost.

The usual fuels employed in enameling may be listed as follows: (1) city gas, (2) oil, (3) producer gas, (4) electricity, (5) coke, and (6) coal.

Much may be said as to the relative advantages of each of these fuels. City gas appears to be unquestionably excellent in meeting all of the requirements stated above although it is not the cheapest fuel from the

standpoint of operating cost. City gas is clean, controllable, reliable, and uniform.

Fuel oil is a commonly used source of heat, and when properly employed will give excellent results. It has the advantage of being lower in first cost than city gas under some conditions, but is not quite so controllable, clean, or reliable as city gas.

Producer gas, under most conditions, is not as desirable a fuel as city gas or oil. The cost of producer gas is frequently underestimated and where proper allowance for overhead is made producer gas will frequently show a higher operating cost than either oil or city gas. Producer gas is usually subject to considerable variation in quality and cleanliness. For these reasons it is not as easily controlled as city gas or oil, and from the standpoint of uniformity and reliability, it is sometimes subject to question.

Electricity is a highly desirable source of heat from practically every standpoint except that of economy and flexibility. In most cases, the operating cost of electrically heated equipment is higher than in the case of fuel heated furnaces. Another difficulty inherent in electrically heated enameling furnaces is the relatively small production obtainable with a given investment. This can thus be illustrated by pointing out that a furnace which will produce 1000 square feet of enameled material per hour, when heated by city gas, would if heated by electricity produce less than half the output. For this reason the first cost of the installation of an electrically heated enamel plant is likely to be much greater than a fuel heated plant.

Coke and coal are solid fuels which apparently are being rapidly displaced in the enameling field. Aside from the low first cost of the fuel itself, there is little to recommend them. Usually the low first cost of the fuel is more than counter-balanced by the additional labor and attention, the increased skill required on the part of the operators, and the tendency to involve relatively large losses in the form of defective ware.

CONTINENTAL INDUSTRIAL ENGINEERS, INC.,
CHICAGO, ILLINOIS

Discussion

MR. MILLER:[1] The furnace shown happens to be in my territory and it might be interesting to give some figures on it.

Area of hearth: 5 feet wide, 12 feet deep.
Output: Ranges from 600 to 1,500 square feet, with average of 1,000 square feet per hour.
Gas Consumed: 4,000 cubic feet per hour
Heats per hour: 35

[1] Public Service Company of Northern Illinois.

Charges per hour: Average of 25 to 30
Temperature Range: 1600° to 1700°
Rate of work: From 7,000 to 12,000 pounds, depending on weight of material

These figures cover a test of 188½ hours. The furnace was operated ten hours a day and shut down over the night period. The actual operating time per day, was about 12½ hours. It was operated 12½ hours and shut down 11½ hours, with a temperature drop of 150°.

MR. VODIKA:[1] How much gas per hour does this furnace consume? What is the B.t.u. value and how much does it cost per thousand cubic feet?

W. A. DARRAH: The furnace consumes 4,000 feet of gas per hour, has a heat value of 530 B.t.u. per cubic foot and the cost is 72 to 73 cents per thousand cubic feet.

B. F. WAGNER:[2] It is not quite clear in my mind as to the difference between a single and double valve control.

W. A. DARRAH: The single valve is used under conditions where the gas is at sufficient pressure so that in going through the orifice it draws in automatically sufficient air for complete combustion. In some cases the air mixes with the gas before delivery to the burner. The single valve has certain advantages which are rather questionable in actual practice. A single valve control will always draw in the same amount of air, providing the air pressure, the gas pressure, and the air temperature is constant. We do not have these three things held constant very often, and where they are not constant the mere fact that we draw in a certain definite volume of air does not mean that we have proper amount of air for correct combustion. It is very seldom that insufficient air is used. The condition of the flame tells you of insufficient air; the flame is yellow. It is a common failing to have too much air, which means a definite loss in fuel efficiency.

The double valve control provides a separate valve to control the gas and a separate valve to control the air. In many cases there is no attempt made to regulate automatically the air and gas together. The criticism is that there is a tendency on the part of the operator to use more air than necessary, thus running up the fuel bill. If a recuperator or regenerator is used to recover a considerable portion of the heat which goes up the stack by preheating the air used, then if the amount of air is increased, it will not result in serious loss of heat. For this reason the heat is taken out of the recuperator and put in the incoming air.

B. F. WAGNER: What was the average temperature of the air delivered by the recuperator?

[1] Aetna Porcelain and Enameling Co.
[2] Coonley Manufacturing Co.

W. A. DARRAH: It is entirely possible to deliver preheated air at a temperature equal to or higher than the stack gases by using a countercurrent circulation. The preheated air ranges from 500° up to 1000° in common cases.

MR. BURT:[1] What is the average temperature drop of the flue gases?

W. A. DARRAH: The temperature of the gases leaving the muffle is usually 2200° maximum, assuming the enameling is done at 1600°. Under those conditions, with a properly designed recuperator, the temperature will drop as low as 600 or 700°.

MR. BURT: Is it possible to overcrowd the furnace by putting in too much ware?

W. A. DARRAH: It is possible to entirely cover the hearth of the furnace. The furnace so far has never been overcrowded as it can handle the work faster than the speed fork can deliver it.

MR. BURT: Can it perfectly handle the largest load shoved at it?

W. A. DARRAH: The first thing that is done to a new furnace is to see what its limitations are. On this particular furnace they have not yet been able to find its limitation. This is controlled by the ability to get work in and out rather than by heat.

MR. BURT: What gas pressure do you use?

W. A. DARRAH: The gas is delivered to the main outside of the furnace at 15 pounds. Gas pressure at the furnace is around eight pounds.

MR. BURT: How many burners are used?

MR. DARRAH: We are using eight burners. In case oil is burned, we use one burner.

BENJ. SKLOVSKY:[2] Do you use a special material in the recuperator to withstand the terrific heat.

W. A. DARRAH: In the recuperator, the lower portion of which is in contact with the highest temperature, a special alloy is used to stand the temperature. The upper portions can either be made of alloy or ordinary steel.

MR. KORMAN[3]: We have considerable difficulty in keeping our temperature drop as low as we do, but have never succeeded in obtaining so small a drop as indicated.

W. A. DARRAH: The furnace has a special arrangement of combustion chambers and flues.

MR. KORMAN: How thick were the refractory brick walls before they were insulated?

---

[1] Trumbull Steel Co.

[2] The Duralloy Co.

[3] Kohler Co.

W. A. DARRAH: Nine inches of fire brick, 4½ inches C22, 9 inches of Sil-O-Cel.

MR. KORMAN: In a plant using fuel oil, what quality of fuel oil produces the best results from the standpoint of Baumé, flash point and sulphur content?

W. A. DARRAH: We have burned fuel oil in various cases and our experience has been that we naturally get the greatest B.t.u. from the heaviest oil. You will not get it, however, unless the oil is thoroughly heated and preferably burned with preheated air.

MR. KORMAN: At approximately what temperature would you call that?

W. A. DARRAH: The temperature to preheat the oil is the flash point. Using Mexican oil, 250° F and if possible heat the air to 600 to 1000°.

MR. HEISEL:[1] What is the difference in this furnace that makes it radically different from some others as to flow of gases or contour.

W. A. DARRAH: There are certain arrangements of flues and methods of burning gases which are rather different in this furnace from most furnaces and unfortunately at the present time our patent counsel will not permit us to talk a great deal on the interior construction.

DYNAMIC SYMMETRY[2]

BY MARIE GUGLE

ABSTRACT

A discussion with examples of the ratios in dynamic designing of ceramic ware.

Since the days of classic art, artists have used what is called static symmetry. The dimensions of its designs are commensurable. Their lengths and widths have real arithmetic measures. The geometry of static design consists of regular geometric figures, perhaps superposed at different angles, as two squares put on top of each other at an angle of 45°. The art of the classic periods in Egypt and Greece used a more subtle proportion, as was recently rediscovered by the late Jay Hambidge of Yale University. He gave it the name of dynamic symmetry. In designs of this proportion, the dimensions are incommensurable. The most common ratios are 1 : 2, 1 : 3, and 1 : 5. Dynamic designs are evolved by the use of areas rather than by line measurements. They are based on root rectangles which have the foregoing ratios.

---

[1] The Chas. Taylor Sons Co.

[2] Received December 1, 1925. See also G. M. A. Richter, "Dynamic Symmetry as Applied to Pottery," *Jour. Amer. Ceram. Soc.* **8** [3], 131-37 (1925).

PROBLEM I

TO DRAW ROOT RECTANGLES

(*a*) Draw a square and its diagonal. Use the side of the square and its diagonal as the dimensions of a rectangle.
The result is a *root-two rectangle.*

(*b*) Use the side of the square and the diagonal of the root-two rectangle as dimensions of a *root-three rectangle.*

(*c*) Continue the process to produce a root-four rectangle (which is a double square), and a *root-five rectangle.*

In dynamic symmetry, there are two other basic figures. One is the reciprocal rectangle and the other is the whirling square.

PROBLEM II

TO DRAW A RECIPROCAL RECTANGLE

(*a*) Draw a root-two rectangle and its diagonal. From one of the opposite vertices, draw a line perpendicular to the diagonal and produce it to meet the opposite side. The new rectangle is a reciprocal root-two rectangle. Its area is

$$\frac{1}{\sqrt{2}} = \tfrac{1}{2}\sqrt{2} = \tfrac{1}{2} \text{ of } 1.414 = .707$$

(*b*) In a similar manner draw a reciprocal root-three rectangle.

$$\frac{1}{\sqrt{3}} = \tfrac{1}{3}\sqrt{3} = \tfrac{1}{3} \text{ of } 1.732 = .577$$

(*c*) In a similar manner draw a reciprocal root-five rectangle

$$\frac{1}{\sqrt{5}} = \tfrac{1}{5}\sqrt{5} = \tfrac{1}{5} \text{ of } 2.236 = .447$$

PROBLEM III

TO DRAW ROOT-RECTANGLES IN A QUADRANT

(*a*) Draw a square $ABCD$ and the diagonal AC.

(*b*) With A as a center and AB as a radius draw the quadrant DB cutting AC at E.

(*c*) Through E draw the line FG parallel to AB. Then $ABGF$ is a root-two rectangle in the square AC.

(*d*) Draw the diagonal AG, cutting the quadrant at H.

(*e*) Through H, draw the line IK parallel to AB. Then $ABKI$ is a root-three rectangle in the square AC.

(*f*) By continuing the drawing of diagonals and parallels, root-four and root-five rectangles may be constructed.

PROBLEM IV

TO DRAW DESIGN PATTERNS FROM ROOT-TWO RECTANGLES

(*a*) Draw a square $ABCD$ and a root-two rectangle on the side AB.

(*b*) In like manner draw a root-two rectangle on DC; on AD; on BC.

(*c*) These overlapping root-two rectangles divide the square into five smaller squares and four root-two rectangles.

By drawing various diagonals in the smaller parts an almost infinite variety of design units may be evolved. Among the seventy-five slides

available in this discussion, about fifteen showed different design patterns with some of the designs themselves as worked out in patterns for silks or book covers.

Other slides showed how dynamic symmetry is the key to the maple leaf; how the plan of the dragon fly is based on the root-three rectangle; and that while we do not see much resemblance between the dragon fly and the iris, yet both are made on the same geometric pattern. The side view of the iris fits into the dynamic root-three pattern. Such a view shows the growing plant and dynamic means growth or power. It was interesting to note in the next group of slides that when the flower comes to fruition as shown in a top view, it fits into a regular equilateral triangle with a smaller one within, which, of course, is a static symmetry pattern. The construction of this static pattern is made, not by drawing two triangles, but by drawing the root-three rectangles, its diagonals and perpendiculars, extending them to make the sides of the outer triangle and connecting the two poles and the mid-point of the base to form the inner triangle. Static symmetry, therefore, is the outgrowth and completion of the dynamic symmetry just as the bloom is the completion of the growing plant.

Problem V

To Draw a Root-Five Rectangle in a Square

(*a*) Draw a square $ABCD$.
(*b*) Within the square, draw a semicircle on the side AB, whose mid-point is O.
(*c*) Draw OC and OD, i.e., the diagonal of half of the square. These lines cut the semicircle at E and F.
(*d*) Through E and F draw GH.
(*e*) $ABHG$ is a root-five rectangle.
(*f*) If the side HB is unity, then AB is $\sqrt{5}$ or 2.236 and EF as well as $E'F'$, its projection on AB, is equal to 1.
Then, $AE' = F'B = \frac{1}{2}(2.236 - 1) = .618$.
And, $AF' = E'B = 1.618$.

In the root-five rectangle the figure AF or $E'H$ is a whirling square. Its ratio is 1.618 which is the reciprocal of .618; for $1/.618 = 1.618$. This ratio .618 will be recognized as that resulting from dividing unit in extreme and mean ratio, or the golden section of the Greeks. A line is divided in extreme and mean ratio if the whole line is to the longer segment as the longer is to the shorter segment.

Problem VI

To Draw a Whirling Square

(*a*) Draw a square $ABCD$.
(*b*) From O, the midpoint of AB, draw OC.
(*c*) With O, as a center and OC as a radius, draw the arc CE, meeting AB produced at E.
(*d*) On AD and AE, complete the rectangle $AEFD$, which is a whirling square rectangle, whose width is 1 and whose length is 1.618.

Problem VII

To Draw a Root-Five Rectangle from a Whirling Square

(*a*) Use the figure of Problem VI.

(*b*) From *O*, draw the arc *DG*, and complete the rectangle on the opposite end in a similar manner. Then the whole figure *GEFH* is a root-five rectangle.

For, $AB = 1$

$GA = .618$

$BE = .618$

Therefore, $GE = 2.236. = \sqrt{5}$

Because the root-five and whirling square rectangles are so intimately related, these two types may be combined in the same design.

Problem VIII

To Show the Reason for the Name Whirling Square Rectangle

(*a*) Draw a square *ABCD* and on it construct the whirling square rectangle *AEFB*.

(*b*) Draw the diagonal *AF*, which cuts *BC* at *G*.

(*c*) Through *G*, draw *GH* parallel to *BE*.

(*d*) Then *BEHG* is a square.

(*e*) Within the rectangle *HC*, draw on *HF* the square *HFIJ*.

(*f*) Continue to draw squares on the end of each remaining rectangle.

(*g*) These squares form a series of squares which whirl around a point or pole on the diagonal.

(*h*) This process may be reversed thus: start with a small whirling square, then draw an external square on the length of the original whirling square, then another square on the length of the new rectangle. Each new square makes an enlarged whirling square rectangle out of the whole figure.

Problem IX

To Draw a Reciprocal Whirling Square Rectangle

(*a*) Draw any whirling square rectangle and its diagonal.

(*b*) From one of the other vertices draw a perpendicular to the diagonal, produce it to meet the opposite side and complete the rectangle. The new one is the reciprocal of the original. The intersection of the diagonal and perpendicular is an *eye* of the whirling square.

Since each of the two diagonals may have two perpendiculars, there are four possible eyes in a whirling square rectangle. By drawing parallels through these eyes, a pattern is obtained which offers the possibility of an almost infinite number of variable designs. A series of slides showed a few of these patterns and related rectangles, as the 1.382 rectangle and the .4472 rectangle or the reciprocal root-five. All of these shapes abound in Egyptian and Greek art. These derived shapes and their applications to Egyptian bas-reliefs and to Greek vases are too complicated to be described without the slides but with the illustrations they are a fascinating study. Another construction of the whirling square rectangle within a square showed also the division of the side of the square in the golden section or in extreme and mean ratio.

The other series of slides showed (1) the relation between the whirling square and the plan of leaf distribution in plant growth; (2) the relation of the pentagon and maple leaf and the 1.809 shape, which was much used in two types of Greek vases, the amphorae and skyphoi; (3) the .691 shape which is the key to the Parthenon and to many Greek vases.

Other slides showed a Greek frying pan of the sixth century B. C.; a group of designs from the strawberry plant based on root-five and whirling square rectangles; a picture of the Nolan amphora from the Fogg Museum of Boston as it fits into its dynamic symmetry pattern based on a 1.7071 shape, which is a square and a reciprocal root-two rectangle; and a beautiful Kantharos of the fifth century B. C. now in the Boston Museum of Fine Arts, whose dynamic symmetry pattern is based on a compound shape derived from a root-five rectangle.

We find that dynamic symmetry was used by the ancient Greeks and then in the middle ages artists dropped back to static symmetry. It has been shown that the great artist, the Creator himself, used dynamic symmetry, as shown by the butterfly, which fits into the root-five and whirling square design. The human skeleton has been found to fit into dynamic symmetry. The Greeks probably discovered these ratios through a study of nature and then applied them to their own temples and vases.

Within the last few years modern artists, as the late George Bellows, Howard Giles, and Leon Kroll, have revived these ratios by using them in their drawings and paintings. It is hoped through a study of Hambidge's rediscovery of the principles underlying the subtile beauty and satisfying proportions of Greek art, that modern artists will help to make this world more beautiful.

Assistant Superintendent of Schools,
Columbus, Ohio

MODERN CERAMICS OF ART[1]

By Carl Bergmans

Abstract

A brief survey of American ceramic art and a plea for ceramic art training complementing courses in ceramic engineering.

Our ceramic industry, following the course of all modern industries, measures achievements in terms of mass production and low cost. Mechanical devices have superseded the craftsman, technology predominates and the beauty of a product is of secondary importance to the manufacturer. This spirit does not exist in America only, but in every country.

The subject of importation of ceramic ware has received lately a great deal of attention and, although we do not wish to give the matter undue importance, we shall briefly review it here.

A certain amount of foreign ware is absorbed by our domestic market because of its low sale price. We are still familiar with the pre-war

[1] Received December 19, 1925.

"made in Germany" mark which was followed by "made in Japan," while now the "made in Czechoslovakia" seems to gain in popularity. Such ware has no artistic merit, it is even of poor material quality and its importation should be curtailed by tariff legislation.

Next, but in a lesser amount, we buy so-called imported artistic pottery, as is the case with a great many other things imported, such as furniture, paintings, tapestries and what not, our merchant's prices and tags only are related to art. Such ware are really manufactured for exportation and we will not always be deceived as to its real value.

The condition prevailing in production of pottery having real artistic merit is very similar in every country, including America. This pottery is produced in small quantity by a few individuals, especially in France, and by such establishments as Sèvres, Copenhagen, our own Rookwood Pottery, and a very few others. Its importation will never be a menace to our national industry but it should be encouraged for our own benefit. Such ware is modern, it does not copy styles of the past; in it the craftsman has interpreted our new needs and our better feelings.

In matters of art, the world regards us with skepticism. They watch our eagerness to absorb all that expresses their past, while their own most advanced elements are endeavoring to create an environment that will fit and express more adequately modern needs, feelings and thoughts. Although not so widely advertised, such elements also exist here but they should be encouraged.

In our country, the quantity of faience tiles used to decorate modern homes is increasing considerably. So far, the artistic value of the material is mainly dependent on new glaze textures and original combination of colors and shapes. Architects are becoming more familiar with the production of this material and its real decorative possibilities. As could be expected, large manufacturing concerns have attempted to handle this product by machinery. This resulted in eliminating the worthwhile character and value of the original product. Happily, it is not being preferred to that which is hand made.

We are economically successful. Most of us can enjoy securely, in ease and comfort, all that human ingenuity has devised for that purpose. Is it not logical that we should now direct our minds toward loftier ideals than just making money? To refine ourselves by understanding and enjoying what is produced by artistic means we may leave behind a finer expression of the best that we know is dormant in us.

Our manufacturers should appreciate that our people, through their purchasing power, are rapidly developing their sense of selection, which means that there is an increasing market for a more artistic product, aside from the economic importance of this fact, should we not pride ourselves in working up to it.

This brings us down to the matter of educating youths in producing artistic ceramic ware. It cannot be denied that there is need for ceramic art schools. Such schools could be established in connection with present state institutions such as the ceramic engineering schools in Ohio, Illinois and New York.

In our large factories, whose success is dependent on the appearance and beauty of their product, one is indeed surprised at the scarcity of craftsmen employed having had even an elementary art education. The majority are untrained and uneducated youths, with factory experience of a practical sort, but whose work is limited to copying, and badly at that. There are few foreign craftsmen of real worth in this country.

Preceding the foundation of ceramic art schools, there should be some understanding in regard to the future of the coming school graduate. Manufacturers should be asked to coöperate and prizes should be offered by competition. The pecuniary reward should be measured by the value and importance of the work.

Ceramic art is not only an art of imagination. The creation of forms involves the knowledge of rules of equilibrium, proportion, and especially usage. As an art of material realization, it requires a practical mind, common sense, a steady method and a sure knowledge of the trade, material, process and technique. To create work that will last and be a worthwhile contribution to his time, the modern designer and craftsman must be inspired by his contemporaries' tendencies, customs and fashions. These in mind, he assumes leadership by giving form to his conceptions and bringing them to the understanding of the layman.

A ceramic engineer's education should include at least a course in ceramic art history. This will tend to make him visualize the ultimate end of his work. May we not hope that it will awaken the interest of some of the students and determine their selection for the particular part of the industry for which they feel more fitted? In our industry, the engineer must work in harmony with the artist, the ultimate success is dependent on the unity of purpose to realize a common aspiration and, although the engineer must exert his cold and calculating faculties he must also understand the artist who is governed mainly by his feeling.

CONTINENTAL FAIENCE AND TILE COMPANY,
SOUTH MILWAUKEE, WIS.

ACTIVITIES OF THE SOCIETY

OUR ANNUAL MEETING

(Atlanta, Macon and Wilkinson Co., Ga. February 8–13, 1926)

With 167 original papers, 32 of them preprinted, and with 27 topics for symposium discussion; with an exhibit, the space for which is larger than in any previous year and nearly all taken; with an advance hotel reservation unprecedented; and plans by the local committees for entertainment way beyond the usual, makes this 1926 Annual Meeting loom in the horizon of expectancy as being larger, more instructive and more enjoyable than any of those the SOCIETY has yet held.

The rail fare to Atlanta will average less for the members than to any point on the Mississippi river or the Atlantic coast. One and one-half fare on certificate plan makes this trip inexpensive.

Those who cannot attend this Meeting will miss one of the finest of opportunities to obtain those bits of information, those personal contacts and those broadening influences which mean so much to one's value in general and one's progress in his vocation.

Of glass and vitreous enamels Georgia has none, but of materials usable in the production of these products Georgia has plenty. Those who have accomplished big things in glass and vitreous enamels will be at the Meeting, and it appears certain that meeting and discussing problems with them will be very much worth while.

The clay products producer will find interest in this meeting and the excursions beyond the usual. Georgia has materials, market, climate and best of all wonderfully fine and enterprising men and women.

The ladies will be entertained to a degree and in ways which will impress this Meeting on their memories as no other meeting has done. The printed program does not adequately reveal the fine times that await the ladies.

Anxious to grasp your hand and renew acquaintance with you will be a record number of ceramists. We hope not many of our members will have to forego attending this Meeting.

NEW MEMBERS RECEIVED FROM DECEMBER 15 TO JANUARY 15

PERSONAL

M. E. Anderson, Supt. Molding Dept., Wellsville Fire Brick Co., Wellsville, Mo.

Andrew Ramsay Bain, The Whins, 26 Park Terrace, Stirling, Scotland. Asst. Works Manager, Messrs. J. G. Stein & Co., Ltd.

Edward R. Berry, 30 Hancock St., Malden, Mass. Asst. Director, Thomson Research Lab., General Electric Co.

George C. Betz, Instructor, Ceramic Department, Rutgers Univ., New Brunswick, N. J.

Finley B. Campbell, 2295 Lumber St., Chicago, Ill., Chicago Mgr., Pacific Coast Borax Co.

James Gilmore Carlisle, 1257 Railway Exchange Bldg., St. Louis, Mo. General Freight Agent, Missouri Pacific Railroad Co.

Samuel Taylor Coleman, III. Box 347, Macon, Ga. Cherokee Brick Co.,

John Galloway Cowan, 84 Wolverhampton Road, Stafford, England. Research Chemist, The Universal Grinding Wheel Co.

William Drayton, Greendale, Ohio. Supt., Hocking Valley Products Co.

Kenneth Webster Dunwody, Box 347, Macon, Ga. General Supt. Cherokee Brick Co.

Emile E. Francais, Box 102, Lorain, Ohio. In charge of enameling dept., National Stove Co.

Harold Bertram Gray, Box 8, Station D., Vitreous Enameling Co., Cleveland, Ohio. Superintendent.

Hermann Harkort, Berlin-Tegel, Gabrielestr. 10, President, German Ceramic Society.

Richard Ambrose Hart, 301 Atlas Block, Salt Lake City, Utah. Secy.-Mgr., Western Clay Products Assn.

Madeline Flint Hosmer, 208 Geneva St., Decatur, Ga., Ceramic Dept., Georgia School of Technology.

John C. Hudgins, Chief Chemist, Taylor Instrument Co., Rochester, N. Y.

John M. Jeffery, 68 Forest Hill Road, Toronto, Canada. Student, Univ. of Toronto.

Edward Kelley, Tabor Road and Godfrey Ave., Philadelphia, Pa. Secy.-Treas., Keystone Brick Co.

C. A. Kemp, Sheet Metal Products Co., Toronto, Canada.

Rufus Howard King, 200 Fifth Ave., New York City. Salesman, Robeson Process Co. and American Gum Products Co.

Gustav Kopka, Karlsbad, Czechoslovakia. Professor at the special school of china industries and manager of technical office of china factories concern.

Bernard Long, 1 bis Place des Saussaies, Paris, France. Directeur du Laboratorie des Glaceries de la Cie de St. Gobain.

Charles Azel Lusby, Drawer D, Amherst, Nova Scotia. Secy-.Treas. and Director, Amherst Foundry Co., Ltd.

Michael McNerny, 553 W. Chestnut St., Lancaster, Pa. Manager of plants for J. C. Budding Co.

Henry Silliman McQueen, Lock Box 138, Rolla, Mo. Geologist, Missouri Bureau of Geology and Mines.

Robert H. Miller, 3324a Halliday St., St. Louis, Mo. Vice Pres. and Gen. Mgr., Farber Fire Brick Co.

Joseph Patrick, 353 Flinders Lane, Melbourne, Victoria, Australia. Director, Shanks & Co., Ltd.

W. Alrich Price, Manager, Price Brick Co., Chester, Pa.

William R. Royer, Wyoming, Pa. President and Gen. Mgr., Anthracite Brick & Tile Corp.

Leo Schwinghammer, 851 Temperance St., Saskatoon, Sask., Canada. Student, Univ. of Saskatchewan.

Stephen M. Swain, 3620 Terrace St., Pittsburgh, Pa. Junior Fellow, Mellon Institute.

Wallace Thoreson, Clayton, Wash. Ceramist, Washington Brick Lime and Sewer Pipe Co.

Erling K. Thorkildsen, Box 724, Lisbon, Ohio. Free hand turner, R. Thomas and Sons Co.

Wm. N. Vodrey, Vodrey Pottery Co., East Liverpool, Ohio.

Edward Richard Walsh, 605 E. Chestnut St., Louisville, Ky. Chemist, Louisville, Fire Brick Works.

L. R. Whitaker, Gainesville High School, Gainesville, Ga. Teacher (High School) and Ceramist, M. D. Hudson Brick Co.

Geo. A. Wills, 103 W. Norwich Ave., Columbus, Ohio, Student, O. S. U.

CORPORATIONS

Beaver Refrigerator and Potteries Co., (Manuf. Sanitary Ware) New Brighton, Pa., A. R. Mitchell, Mgr.

Claycraft Mining and Brick Co., (Face and Common Brick) 907 Hartman Bldg., Columbus, Ohio. C. Forrest Tefft, General Factory Mgr.

Consolidated Slip Clay Corp., (Miners and Shippers of Albany Slip Clay) 295 West Laurence St., Albany, N. Y. E. J. B. Murray, Vice Pres.

The O. Hommel Co. (Ceramic Colors and Supplies) 209 4th Ave., Pittsburgh, Pa. O. Hommel.

Malleable Iron and Range Co., (Manufacture Kitchen Ranges) Beaver Dam, Wis. L. S. Weimer.

Trent Tile Co., Inc., (Floor, Wall, Trim Tile) Trenton, N. J. Thomas H. Thropp

Westinghouse Lamp Co., (Manuf. Incandescent Lamps and Radio Tubes) Bloomfield, N. J. Albert Brann.

Membership Worker's Record

	Personal		Personal	Corporation
Mrs. Julia F. Baccus	1	H. A. Plusch		1
C. E. Bales	1	W. D. Richardson	1	
L. E. Barringer	1	W. L. Shearer	1	
H. T. Bellamy	1	J. L. Silvers		1
M. C. Booze	1	P. A. Smith		1
K. H. Endell	1	Alan Stein	1	
W. C. Fisk	1	E. Ward Tillotson	1	
P. D. Helser	1	W. E. S. Turner	1	
A. V. Henry	2	Hewitt Wilson	1	
R. A. Horning	2	H. G. Wolfram	1	
M. R. Hornung	1	A. S. Zopfi	1	
A. H. Kuechler	1	Office	13	4
S. J. McDowell	1		—	—
R. J. Montgomery	1	Total	37	7

Members Whose Addresses Are Unknown[1]

All-in-one Plumbing Fixture Corp., 231 Ochsner Bldg., Sacramento, Calif.

Paul S. Bachman, 3002 4th Ave. W., Seattle, Wash.

G. V. Baker, Penn. Feldspar Co., Barnard, N. Y.

J. O. Benson, Carr-Lowrey Glass Co., Baltimore, Md.

William Birner, Box 139 R. R. No. 1, East San Gabriel, Calif.

Leo T. Butman, F. R. Muller & Co., Waukegan, Ill..

J. P. Callaghan, c/o Teaque Hotel, Montgomery, Ala.

T. M. Caven, 564 W. 173rd St., New York City.

K. T. Chiang, 609 W. 115th St., Apt. 8, New York City.

[1] Kindly notify Secretary's office if you have information of the location of these members.

Frank J. Connors, Y. M. C. A., Winsted, Conn.
August F. Danes, 5937 Arsenal St., St. Louis, Mo.
William M. Decker, Jr., 32 St. James Place, Buffalo, N. Y.
Charles S. Dolley, Keramoid Mfg. Co., Fort Madison, Iowa.
S. P. Edson, Bryantville, Mass.
M. S. Gifford, Lake Bluff, Ill.
A. H. Goodman, Box 915, Pittsburgh, Pa.
John L. Greenwood, Lehigh Sewer Pipe & Tile Co., Lehigh, Iowa.
C. Knox Harding, 6318 Stony Island Ave., Chicago, Ill.
Mario F. Hasselmann, Caixa Postal 1546, Rio de Janeiro, Brazil.
Kenneth E. Holley, Alfred, N. Y.
Isaac Kahn, 2428 Reading Road, Cincinnati, Ohio.
G. S. Kennelley, 3265 Philadelphia W., Detroit, Mich.
J. M. Knote, J. H. Gautier & Co., Jersey City, N. J.
Roy Lacy, 634 S. St. Andrews Place, Los Angeles, Calif.
Arthur T. Leahy, 5490 Ellis Ave., Chicago, Ill.
William W. Lemmax, Box 59, Taylor, Wash.
George W. Lester, 2176 McClellan Ave., Detroit, Mich.
A. T. Meldram, Strathcona Potteries, 99 St. James St., Montreal, Can.
Max Meth, Blackstone Bldg., Room 512, Pittsburgh, Pa.
C. F. Miller, University of Washington, Law School, Seattle, Wash.
J. H. Minnigerode, Box 935, Baltimore, Md.
F. H. Nies, Corner Hamilton Ave. & Summit St., Brooklyn, N. Y.
H. M. Pulsifer, Manhattan Bldg., Chicago, Ill.
Paul Q. Quay, Ferro Enamel Supply Co., 2100 Keith Bldg., Cleveland, Ohio.
Robert C. Rahn, Western Electric Co., 5144 Lake St., Austin Station, Chicago, Ill.
Gordon W. Reed, 407 S. Dearborn St., Chicago Ill.
A. E. Saunders, 48 Albemarle Ave., Toronto, Ont., Canada.
John Sawyer, 135 N. Hancock St., Los Angeles, Calif.
Lee Showers, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
Olin F. Shults, State School of Ceramics, Alfred, N. Y.
George Sirovy, 1486 Perry St., Des Plaines, Ill.
George A. Speer, 116 Hyland Ave., Ames, Iowa.
Clarence A. Stimpson, Chicago Pneumatic Tool Co., Century Bldg., Chicago, Ill.
Charles H. Stone, Jr., 1210 Oak St., Jacksonville, Fla.
Evelyn Tennyson, Alfred University, Alfred, N. Y.
Erwin F. Theobald, General Delivery, Bessemer, Pa.
Boris Trifonoff, 631 Putnam Ave., Zanesville, Ohio.
Mrs. David Vanderkooi, 733 Michigan Ave., Portland, Ore.
Bernard Vane, Hopewell, Va.
John H. Voorhies, Alfred, N. Y.
Frank A. Weidman, 38 S. Dearborn St., Chicago, Ill.
G. N. White, 7 Victoria Ave., Worcester, England.
Heinrich Willmer, Cologne Nippes, Germany.

ST. LOUIS SECTION MEETING

The members of the St. Louis Section met at Hotel Coronado, St. Louis, the evening of December 17. The meeting was called to order by F. E. Bausch, Chairman, at 8:30 P.M.

C. S. Houpt of the Wrought Iron Range Company, Chairman of the Enameler's Club, gave a discussion of the formation and activities of that Club. Mr. Houpt brought

out that the Enameler's Club of St. Louis is the first of its kind formed and that as a result of the activities of this club other cities are planning the formation of like clubs, such a club having recently been organized in Chicago, along the lines of the St. Louis club. The club consists of 44 members, four of whom are technical men and the balance are practical men. At their meetings round table discussions are held, and free discussions given on problems that arise at various plants, and the members coöperate in arriving at a solution. The St. Louis territory has the distinction of having 19 enameling plants treating porcelain enamel.

R. C. Gosreau, consulting metallurigcal engineer, discussed the limitation of refractory application to metallurgical furnaces and emphasized particularly the fact that refractories are often limited in their life by the manner in which they are placed in the furnace. Mr. Gosreau gave a general survey of the refractory requirements of the iron and steel industry, taking up blast furnaces, stoves, soaking pits, open hearth, and electric furnaces; also treating of the blast, reverberatory and refining furnaces of the copper industry, lead blast furnaces and zinc smelting furnaces. The matter of general application of refractories to all furnaces, as brought out by Mr. Gosreau, is that it is best to keep roof thickness at a minimum point consistent with strength of the arch, because of the fact that undue thickness will serve as an insulator and thereby cause rapid wear on the surface exposed to the flame.

L. C. Hewitt gave a discussion on the matter of refractory specifications, bringing out the limits of present tests in respect to their suitability for forecasting service and the danger that may arise from using these tests in writing specifications, without a thorough knowledge of all factors involved.

Following these papers, a general round table discussion was held. There were thirty in attendance, as follows: F. E. Bausch, 1105 Chemical Bldg.; C. S. Houpt, Wrought Iron Range Co.; E. A. Eigenbrot, Buck Stove and Range Co.; W. D. Thompson, Laclede Gas Co.; W. W. Aulepp, Russell Eng. Co; Wm. H. Weber, Roxana Petroleum Co.; H. W. Weber, and A. O. Schleiffarth, Russel Eng. Co.; J. D. Robertson, Robert W. Hunt Co.; C. B. Kentnor, Jr., Laclede Gas Light Co.; P. H. C. Kieser, and C. W. Berry, Mitchell Clay Mfg. Co.; C. Chake, and C. H. Eichmeyer, Parker-Russell M. & M. Co.; Y. R. Anderson and W. R. Morgan, Evens and Howard; A. F. Seelig, Eagle-Picher Lead Co.; E. O. McFadon, Karr Range Co., Belleville, Ill.; A. H. Sullivan and D. A. Scullin, A. H. Sullivan Foundry and Ceramic Metals Co.; N. Epstein, Industrial Eng. and Equip. Co.; H. W. Perry, T. E. Wood, Laclede Gas Company; H. P. Williams, L. H. Blue, John B. Lyon, H. E. Johnson, L. C. Hewitt, and A. F. Danes of the Laclede-Christy Clay Products Co.

L. C. Hewitt, *Secy.*

ST. LOUIS SECTION DINNER DANCE

Members of the St. Louis Section and their friends held a dinner-dance at the St. Louis Club, Saturday evening, January 16. This party was one of most enjoyable gatherings the St. Louis ceramists have had.

NOTES AND NEWS

CERAMIC SCHOOL AT ROLLA

Rolla, Mo., Dec. 31. A course in ceramic engineering is to be added to the curricula of the School of Mines and Metallurgy at Rolla, the announcement being made following a meeting of the executive committee of the Board of Curators of the School at the Statler Hotel in St. Louis yesterday.

A committee representing the clay industries of Missouri has been working on the matter for some time placing before the school authorities facts to justify their demand for a course of this kind. The clay industries of Missouri have been growing at a very rapid rate in recent years, until today Missouri stands second among the states as a producer of clay. The following tabulation will give an idea of the relative value of the clay industry in the state as compared with other mineral industries:

Products	Value, 1921	Value, 1924
Lead	$16,207,650	$28,279,183
Clay products and raw clay	11,606,826	18,363,904
Coal	13,915,500	11,600,000
Zinc	1,084,500	2,516,332

Members of the Industrial Committee of the Clay Association stated that there was a good demand for men trained in this branch of engineering, and that the Missouri industries have been compelled to go to the schools in the East for such men. They felt, after a survey of the schools of the State, that the School of Mines and Metallurgy would be the logical place to offer such training in this State. There will be presented to the legislature at its next session requests for appropriations for the financing of the department.

Dr. Chas. H. Fulton, Director of the School, stated that the new department would be open for registration next fall, and that he would begin at once to endeavor to find a man of demonstrated ability in this branch of learning to fill the new professorship.

To encourage Missouri boys who may be interested in the study of ceramics, the Missouri Clay Association will also offer several scholarships, the details of which are now being worked out.

SHORT COURSE AT UNIVERSITY OF ILLINOIS

The Short Course in clay working and enameling was given at the University of Illinois, Department of Ceramic Engineering, January 11 to 23 inclusive. C. W. Parmelee, professor of ceramic engineering and head of the ceramic department added to the teaching staff for this special course. M. C. Booze of Mellon Institute, Pittsburgh, who lectured on "refractories"; R. R. Danielson of A. J. Lindemann and Hoverson Co., Milwaukee, Wis., on "enamels" and A. S. Watts of the department of ceramic engineering of Ohio State University on "bodies."

Other instructors from the University of Illinois who assisted with this course were: M. S. Ketchum, dean of the college of eng. and director of the Eng. Exp. Station; S. W. Parr, prof. of applied chemistry; E. B. Paine, prof. of electrical eng.; O. A. Harker, prof. of law; B. W. Benedict, mgr. of the machine shop labs.; A. P. Kratz, research prof. of mech. eng.; A. M. Buswell, chief, Ill. State Water Survey; A. C. Callen, prof. of mining eng.; R. K. Hursh, assoc. prof. of ceramic eng.; A. I. Andrews, asst. prof. of ceramic eng.; A. E. R. Westman, research assoc.; C. H. Casberg, supt. of the machine shop lab.; T. N. McVay, instructor in ceramic eng. and E. G. Bourne, lab. demonstrator in ceramic eng.

About 50 students were enrolled in the Course, of which about 10 had attended previous courses of this kind at the University of Illinois. Practically all those registered for the Course were connected with the heavy clay industries, the whiteware industries being represented by less than 10 men. Much interest was displayed in the enamel course which is represented by many manufacturers in this part of the United States.

Included in the registration of this course were: 1 from Colorado, 2 from Georgia, 15 from Illinois, 8 from Indiana, 1 from Iowa, 1 from Maryland, 1 from Michigan, 2 from Missouri, 1 from Nebraska, 1 from New Jersey, 2 from Pennsylvania, 5 from Ohio, 3 from Wisconsin, 1 from Kentucky. Total of 39 from 14 states.

The attendants were highly enthusiastic and expressed absolute confidence that the benefit derived more than repaid them for the time and expense of coming to the University for this Course. Prof. Parmelee is to be congratulated on the continuation of this Short Course which has been attempted elsewhere but never with the success which the University of Illinois has enjoyed.

A PHAMPHLET ISSUED BY DEPARTMENT OF MANUFACTURE CHAMBER OF COMMERCE OF THE UNITED STATES

Research or a pursuit for facts and better methods along scientific lines is widely recognized as an indispensable adjunct to good business operation. Coöperative research constitutes one of the most constructive activities of trade associations and is, moreover, an effort which receives a surprising amount of financial support from manufacturers. The Department of Manufacture has just completed a study of this industrial movement and has developed some most interesting data from those groups successfully carrying on research programs.

Many phases of the work are touched upon, such as the scope of the effort, the manner in which the studies are conducted, methods of selecting subjects and reporting results, laboratories used, coöperating agencies, cost of research, and methods of financing. In addition, detailed accounts are given of four outstanding association research programs, namely, paint and varnish, canning, baking and printing. Then too, as an appendix a register has been compiled giving the actual research studies conducted by eighty different groups representing many lines of industry.

The purpose of this publication is to briefly chronicle the extensive research efforts being carried on in industry through trade organizations and to present data on various aspects of the work which would be of interest to those in production. Initial copies of the pamphlet may be had upon request to the department.

DEPARTMENT OF MANUFACTURE,
E. W. MCCULLOUGH, *Manager*

EDWARD WRIGHT WASHBURN BECOMES CHIEF OF CHEMISTRY DIVISION AT BUREAU OF STANDARDS

We feel sure that our readers will be greatly interested to learn of the appointment of Edward Wright Washburn as Chief of the Chemistry Division of the Bureau of Standards. For several years Dr. Washburn specialized in ceramic chemistry, and from 1916 to 1922 he was in charge of the Department of Ceramic Engineering at the University of Illinois.

During 1921 and part of 1922 Dr. Washburn successfully edited the *Journal of the American Ceramic Society*.

Since 1922 Dr. Washburn has been the editor of the "International Critical Tables" prepared under the auspices of the National Research Council. He was chosen by a special committee as the man best fitted to fill the difficult post of Chief of the Chemistry Division of the Bureau of Standards, and his appointment was announced by Dr. George K. Burgess, Director of the Bureau, last month.

In his new position Dr. Washburn will have an unusual opportunity to serve the Government, the industries, and the public, because no division of the Bureau has wider contacts than does his. In the development of improved analytical methods, in the preparation of specifications, and in its testing of thousands of samples this division has won for itself an enviable reputation for accurate and worthwhile work.

Dr. Washburn is a graduate of Massachusetts Institute of Technology (1905) and received his doctor's degree from the same institution in 1908. He is widely known as the author of "Principles of Physical Chemistry," and is a member of many scientific and technical organizations.

Dr. Washburn succeeds Dr. W. F. Hillebrand, who died in 1925, and who was for many years chief of this division and internationally known in connection with analytical work.

DEPARTMENT OF COMMERCE—BUREAU OF MINES

Opens Metallurgical Laboratories

The new metallurgical laboratories of the Pittsburgh Experiment Station of the Bureau of Mines, Department of Commerce, formally opened on the evening of January 26. Members of the Metallurgical Advisory Board of Carnegie Institute of Technology and the Bureau of Mines were present. Others prominent in the mining and metallurgical fields attended.

The new metallurgical laboratories are the outgrowth of an agreement made in 1923 under which Carnegie Institute of Technology appointed an advisory board for its Department of Metallurgy and arranged for coöperative research fellowships in metallurgy at the Pittsburgh Experiment Station of the Bureau of Mines.

The equipment of the new metallurgical laboratories includes a modern electric-furnace laboratory well arranged for fundamental work in many branches of the metallurgy of iron and steel; a metallographic laboratory; and a chemical laboratory.

F. W. Schroeder, a chemist, who has done graduate work in ceramics and extensive research work on refractories, will handle the work of the section having to do with the metallurgical requirement of refraction. B. M. Larsen, a chemical engineer, who has specialized in metallurgy, will conduct research problems in the metallurgy of steel. A. K. Hutton handles the analytical work.

The work of the metallurgical section is aided and supplemented by fellowships supported by Carnegie Institute of Technology and by local industries. The four fellows working on metallurgical problems this year are Ralph B. Norton, a graduate of Massachusetts Institute of Technology, in electrochemistry; Gustave H. Pfeiffer, a graduate of Rose Polytechnic Institute, in chemical engineering; Abraham Grodner, a graduate of Carnegie Institute of Technology, in mechanical engineering; and E. A. Hertzell, a graduate of Pennsylvania State College, in chemical engineering.

The problems to be studied by the four research fellows are temperature and heat flow in open hearths; case carburized steel, and open-hearth refractories.

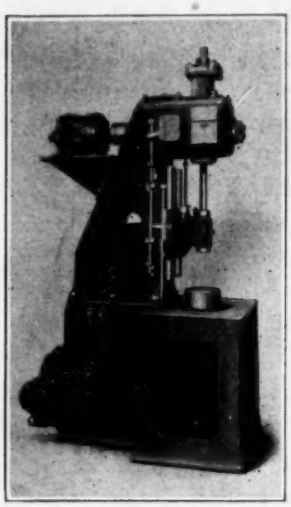
The metallurgical section at Pittsburgh is one of the three metallurgical sections of its Bureau working on ferrous metallurgy, the other two being at Minneapolis and Birmingham.

STAMETS INSULATOR PRESS

The new Stamets Insulator Press is directly connected through a flexible coupling to a special motor and the reversal of the spindle is obtained entirely through electrical control.

The spindle is provided with ball thrust bearings and is guided close to the plunger by a sliding head. The head is on large ways and provided with a tapered gib for taking up wear. The spindle nose is provided with a Morse tapered hole to receive the tapered shank of the plunger so that plunger can be accurately centered and easily removed. Gears are of steel, accurately cut and run in an oil bath.

The machine can be operated with the spindle reversing for insulators having a threaded portion, or by means of quick adjustment the spindle will run in one direction only. An automatic take-up is provided to eliminate lost motion due to wear between the nut and the screw on the spindle.



The insulator mold is carried on a reciprocating carrier which is automatically actuated, providing a dwell at the top of the stroke when the insulator is pressed and the dwell at the bottom of the stroke for loading and unloading. The stroke of the mold carrier is adjustable.

SOCIETY OF GLASS TECHNOLOGY

The two papers read and discussed at the meeting of the Society of Glass Technology at University College, London, Department of Glass Technology at Sheffield. The first entitled "The Composition of Glass Suitable for Use with Automatic Machines" by W. E. S. Turner gave him an opportunity of ranging over the whole field of glass compositions which had been used, particularly for glass bottles, from the time of the Roman glass makers down to the present day. The introduction of the automatic machine had very much limited the range of compositions available. For example, in using a number of types of machines the percentage of lime in the glass could not be raised safely above 10%, whereas in some of the glass used on the Continent and worked by hand the percentage had considerably exceeded 20 without causing excessive difficulty. Prof. Turner then went on to indicate various compositions of glass which had been employed in recent times both in this country and in America, pointing out that the factors which decided the limits of composition were the size of the article, whether colorless or colored, the method by which the machine was to be charged, that is to say, whether by suction or by gob feeding, and finally by the type of machine itself. Scientifically, the factors of importance were the viscosity of the glass, the rate at which the viscosity changed with temperature, the heat conductivity and heat radiation.

In the second paper entitled "The Relationship between the Durability and the Chemical Composition of Glass" by Miss V. Dimbleby and Prof. Turner, the account which was given by Miss Dimbleby was of work which had been proceeding at Sheffield for several years. Glasses were tested of similar type in which soda was replaced successively by lime, magnesia, alumina, titania, zirconia, barium oxide and boric oxide. In all 70 to 80 individual glasses were prepared and the action of the four reagents, namely, boiling water, hydrochloric acid, sodium carbonate and caustic soda solution were tested. The research probably represented the most thorough attempt which had been made up to now to discover the relationship between the durability and the chemical composition.

The ordinary meeting at which the papers were read was preceded by a special general meeting at which a gift of residual funds amounting to about £2,500 was accepted by the Society from the Glass Research Association. The interest on this sum is to be devoted to the writing year by year of a report by some eminent authority on the progress of glass technology.

CALENDAR OF CONVENTIONS

AMERICAN CERAMIC SOCIETY	Feb. 8-13, 1926	Atlanta, Ga.
American Chemical Society (Spring Meeting)	April 5–9, 1926	Tulsa, Okla.
American Concrete Institute	Feb. 23–26, 1926	Chicago, Ill.
Amer. Electrochemical Society	April 22–24, 1926	Chicago, Ill.
American Foundrymen's Assn.	Sept. 27, 1926.	Detroit, Mich.
Amer. Institute of Min. and Met. Engrs.	February 15, 1926	New York City
Amer. Soc. Testing Materials	June 21–26, 1926	Atlantic City, N. J.
Amer. Zinc Institute	April 27–28, 1926	St. Louis, Mo.
Assn. Chemical Equipment Mfrs.	May 10–15, 1926	Cleveland, Ohio.
Ass. Iron and Steel Mfrs.	May 31–June 5, 1926	Chicago, Ill.
Baltimore-Washington Section (American Ceramic Society)	Feb. 6, 1926	Baltimore, Md.
Common Brick Manufacturers	February 22–26, 1926	New Orleans, La.
Manufacturing Chemists' Association	May or June, 1926	Near New York City
Nat. Acad. of Sciences (Spring Meeting)	April 26–28, 1926	Washington, D.C.
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March 9, 1926	Pittsburgh, Pa.
Natl. Assn. Stove Mfrs.	May 12–13, 1926	New York City
Natural Gas. Assn. of America	May 17–20, 1926	Tulsa, Okla.
Sand-Lime Brick Assn.	Feb. 9–15, 1926.	New Orleans, La.

Have You Any of These for Sale?

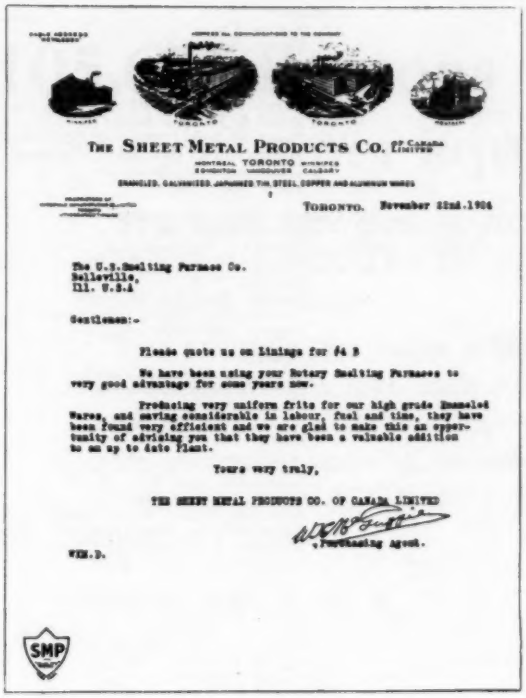
Transactions and Journals Out of Print

Volumes 2, 5, 8, 9, 10, 11, 12, 14, 18 and 19 of the *Transactions of the American Ceramic Society* are out of print. As we have received several requests for these numbers $5.00 will be paid for each copy on receipt in the Secretary's office.

The January and June, 1923 and the January, February, 1924 issues of the Journal are also out of print; 60 cents will be paid for each copy received by

General Secretary,
Lord Hall, O. S. U.
Columbus, Ohio.

LARGE CANADIAN ENAMELING PLANT USING BATTERY OF U. S. ROTARY ENAMEL SMELTING FURNACES



THE SHEET METAL PRODUCTS CO. OF CANADA LIMITED

MONTREAL TORONTO WINNIPEG EDMONTON VANCOUVER CALGARY

ENAMELED, GALVANIZED, JAPANNED TIN, STEEL, COPPER AND ALUMINUM WARES

TORONTO, November 22nd.1916

The U.S.Smelting Furnace Co.
Belleville,
Ill. U.S.A

Gentlemen:-

Please quote us on linings for #4 B

We have been using your Rotary Smelting Furnaces to very good advantage for some years now.

Producing very uniform frits for our high grade Enamelled Wares, and saving considerable in labour, fuel and time, they have been found very efficient and we are glad to make this an opportunity of advising you that they have been a valuable addition to an up to date Plant.

Yours very truly,

THE SHEET METAL PRODUCTS CO. OF CANADA LIMITED

Purchasing Agent.

WM.D.

SMP

Years of Efficient Service

Very Uniform Frits at a Saving in Fuel, Labor and Time

A Valuable Addition

SIZES AND CAPACITIES

No. 1	No. 2	No. 3	No. 4	No. 4-B
60 lb.	150 lb.	350 lb.	750 lb.	1200 lb.

Description, Photographs, Specifications and Prices Mailed Promptly

THE U. S. SMELTING FURNACE CO.

BELLEVILLE, ILLINOIS, U. S. A.

BUYERS' GUIDE

A

Alumina (Hydrate and Calcined)
Harshaw, Fuller & Goodwin Co.
Pennsylvania Salt Mfg. Co.

Alundum (Refratory Products)
Norton Co.

Auger Machines
Chambers Brothers Co.
Freese, E. M. & Co.

Automatic Brick Machinery
Lancaster Iron Works, Inc.

Automatic Cutters
Chambers Brothers Co.
Freese, E. M. & Co.

Automatic Stove Rooms
Philadelphia Drying Machinery Co.

Automatic Temperature Control
Brown Instrument Co.
Engelhard, Chas., Inc.
Leeds & Northrup Co.

B

Balls (Mill)
Alsing, J. R. Eng. Co.

Ball Mills
Alsing, J. R. Eng. Co.
McDanel Refrac. Porcelain Co.
Mueller Machine Co., Inc.

Batts (Alundum-Crystolon)
Norton Co.

Bitstone
Potters Supply Co.

Bituminous Coal
Seaboard Fuel Corp.

Blocks (Refractory)
Norton Co.
Parker Russell Co.
The Massillon Refractories Co. *("Alumite")*

Boats, Combustion
Norton Co.

Boards (Sagger)
Commercial Shearing & Stamping Co.

Borax
American Trona Corp.
Innis, Speiden & Co.

Boric Acid (Crystal, Granular or Powder)
American Trona Corp.
Innis, Speiden & Co.

Brick (Porcelain)
Alsing, J. R. Eng. Co.

Brick Making Machinery
Chambers Brothers Co.
Freese, E. M. & Co.

Bricks (Refractory-Alundum-Crystolon)
Norton Co.

Bricks (High Aluminous—Electrically Sintered Aluminum Oxide—Silicon Carbide)
The Massillon Refractories Co. *("Alumite")*

Burners (Oil)
Best, W. N. Corp.
Harrop. C. B.

C

Cars (Clay)
Lancaster Iron Works, Inc.

Carbonates (Barium-Lead)
Innis, Speiden & Co.

Caustic Soda
Pennsylvania Salt Mfg. Co.

Cements
Norton Co.
Parker Russell Co.

Ceramic Chemicals
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Metal & Thermit Corp.
Paper Makers Importing Co., (Inc.)
Roessler and Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
Vitro Mfg. Co.

Ceramic Plant Equipment
Carrier Engr. Co.
Chambers Brothers Co.
Freese, E. M. & Co.
Harrop. C. B.
Mueller Machine Co., Inc.
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

Clay (Ball)
Harshaw, Fuller & Goodwin Co.
Paper Makers Importing Co.
Potters Supply Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (China)
Drakenfeld and Co., B. F.
Edgar Brothers Co.
Harshaw, Fuller & Goodwin Co.
Paper Makers Importing Co., (Inc.)
Roessler & Hasslacher Chemical Co.
United Clay Mines Corp.

Clay (Electrical—Porcelain)
Edgar Brothers Co.
Harshaw, Fuller & Goodwin Co.
Paper Makers Importing Co., (Inc.)
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Enamel)
Edgar Brothers Co.
Paper Makers Importing Co.
Metal & Thermit Corp.
United Clay Mines Corp.
Vitro Mfg. Co.

Clay (Fire)
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Parker Russell Co.
Potters Supply Co.
The Massillon Refractories Co. *("Alumite")*
United Clay Mines Corp.

Clay (Potters)
Paper Makers Importing Co.
Spinks Clay Co., H. C.
The Massillon Refractories Co. *("Alumite")*
United Clay Mines Corp.

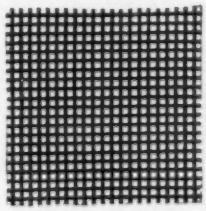
325
325
1625
650
975
105,625

105,625 Reasons per square inch

Fine mesh wire cloth of ACCURATE spacing and ACCURATE diameter of wire is our specialty.

For example, we make a testing sieve of 325 spaces per inch each way. There are therefore 105,625 openings per square inch, and every opening, because of its accuracy, is a REASON why you should invariably specify

"NEWARK" Wire Cloth



Have you our new catalog No. 25?

NEWARK WIRE CLOTH CO.

355-369 Verona Ave., Newark, N. J.

Branch Office:
66 Hamilton St., Cambridge, Mass.

(When writing to advertisers, please mention the JOURNAL)

BUYERS' GUIDE (continued)

Clay (Sagger)
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Parker Russell Co.
Potters Supply Co.
Spinks Clay Co., H. C.
The Massillon Refractories Co. *("Alumite")*
United Clay Mines Corp.

Clay Cleaning Machinery
Lancaster Iron Works, Inc.

Clay Handling Machinery
Freese, E. M. & Co.
Hadfield-Penfield Steel Co.
Mueller Machine Co., (Inc.)

Clay Miners
Edgar Brothers Co.
Paper Makers Importing Co., (Inc.)
Spinks Clay Co., H. C.
The Massillon Refractories Co. *("Alumite")*
United Clay Mines Corp.

Clay Pots
Buckeye Clay Pot Co.

Clay Storage Systems
Harrop. C. B.
Lancaster Iron Works, Inc.

Clay (Wad)
Paper Makers Importing Co., (Inc.)
Potters Supply Co.
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay (Wall Tile)
Papers Makers Importing Co., (Inc.)
Spinks Clay Co., H. C.
United Clay Mines Corp.

Clay Washing Machinery
Mueller Machine Co., Inc.

Clay Working Machinery
Freese, E. M. & Co.
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Melting (Ignition)
Brown Instrument Co.

Cloth (wire)
Newark Wire Cloth Co.

Coal-(Bituminous)—
Seaboard Fuel Corp.

Colors
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

Conditioning Machinery
Carrier Engr. Co.
Philadelphia Drying Machinery Co.
Proctor & Schwartz, Inc.

Cones (Filter)
Norton Co.

Conveyors (Belt Cable)
Lancaster Iron Works, Inc.

Conveyors (Clay, Sand, Brick, etc.)
Hadfield-Penfield Steel Co.
Philadelphia Drying Machinery Co.
Mueller Machine Co., Inc.

Controllers (Automatic Temperatures)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

Cores (Alundum Furnace)
Norton Co.

Cornwall Stone
Harshaw, Fuller & Goodwin Co.
Pennsylvania Pulverizing Co.

Crucibles (Filter-Melting-Ignition)
Norton Co.
Potters Supply Co.
The Massillon Refractories Co. *("Alumite")*

Crushers
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Lancaster Iron Works, Inc.
Mueller Machine Co., Inc.

Cutting Machines
Freese, E. M. & Co.

D

Decorating Supplies
Caulkins & Co., H. J.
Drakenfeld and Co., B. F.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

Decorating Kilns
Caulkins & Co., H. J.
Holcroft & Co.

Dental Furnaces
Caulkins & Co., H. J.

Discs (Alundum-Porous-Filter)
Norton Co.

Dishes (Alundum-Filtering-Ignition)
Norton Co.

Disintegrators
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Lancaster Iron Works, Inc.
Mueller Machine Co., Inc.

Dolomite
Innis, Speiden & Co.

Dryers (Brick)
Harrop. C. B.

Dryers (China Ware—Porcelain)
Carrier Engr. Co.
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

Dryers (Steam Pipe Rack)
Lancaster Iron Works, Inc.

Drying Boards
Commercial Shearing & Stamping Co.

Drying Machinery
Carrier Engr. Co.
Philadelphia Drying Machinery Co.
Proctor and Schwartz, Inc.

New Opportunities await some REFRACTORY PRODUCTS *manufacturer*— IN GEORGIA!

Know more about GEORGIA REFRACTORY CLAYS

Write for these interesting bulletins!

Each of these bulletins is an official report of the research and tests with Georgia Refractory Clays for various commercial purposes. They contain no elaboration—just the simple facts of the superiority of Georgia Refractory Clays and other valuable information for those seriously interested in their exploitation and use. Write for any one of them, or all, if you wish.

Utilization of Georgia Kaolins for Refractories.
Kaolin and Refractory Clay Deposits in Wilkinson County, Georgia.
Washing Tests of Georgia Clays.
Georgia Clays for Paper Fillers.
Georgia Clays for Rubber Fillers.
Use of Sedimentary Kaolins of Georgia in Whitewares.
Distribution of Kaolin and Bauxite of the Coastal Plain of Georgia.
Directory of Commercial Minerals in Georgia and Alabama Along Central of Georgia Railway.

NATURE endowed Georgia with generous deposits of higher quality refractory clays, the value of which, for certain commercial purposes, has not been fully realized until recent years.

With the refractory clay deposits fast waning in other sections of the country, and the recent disclosure of Georgia's huge deposits of better clays—today Ceramic experts point to Georgia as the future center for the production of certain refractory products—particularly fire-brick! As a result of extensive tests under actual operating conditions it has been conclusively proven that fire-brick of greater lasting qualities can be made from Georgia Kaolin alone—just one material!

As an established manufacturer of fire-brick or other refractory products, contemplating expansion or seeking an additional plant site closer to a better raw material source—Georgia beckons you to investigate the unusual opportunities that await you in the South—NOW!

These Tests Proved the Superiority of Georgia Kaolin for Fire-Brick

Ordinary fire-brick usually falls, in the bottom of an open-hearth ladle, after two or three weeks' service through spalling and disintegration. Georgia Kaolin brick in a ladle, at mid-west plant, were in exceptionally good condition after eleven weeks' service! This test proved Georgia Kaolin brick to give 266 percent better service than that rendered by commercial brands tested similarly. Other tests showed Georgia Kaolin brick to be at least equal, and in the majority of cases superior, to fire clay and silica fire-brick—in one instance 29 percent better and in another 220 percent! Georgia Kaolin shows a deformation value from cones 34 to 39 and better load carrying capacity, as well as exceptional resistance to spalling.

Extensive Deposits of Georgia Refractory Clays

The refractory clay and Kaolin belt of Georgia extends from Augusta to Columbus, covering an area of approximately 10,000 square miles. These deposits are the largest in the Eastern section of the country. In Wilkinson County alone (just one of 15) there is sufficient raw material to supply the needs of the ceramic and filler industries of the country for over 600 years, at the present rate of Kaolin clay consumption.

Easy to Mine—Mostly Surface Deposits

The Georgia refractory clay deposits are mostly surface deposits and are easily and economically worked with steam shovels. Overburden varies from 5 to 20 feet and usually consists of loose red sand and occasionally fullers earth. Deposits run from 10 to 40 feet deep. Crude clay can be mined in quantity at a cost of from 30 to 40 cents a ton as compared to an approximate cost of $1.50 to $2.00 a ton where underground mining is necessary.

Cheaper to Manufacture Georgia Kaolin Fire-Brick

The fire-brick put to the tests heretofore mentioned, was made of only one material — Georgia Kaolin! This clay enables you to make a better fire-brick from one clay only—an economic advantage of great importance in the cost of production! Power is reasonable and labor plentiful. Present price of labor in the Georgia clay district is from 17½ to 20 cents per hour. Fuel oil costs 6½ cents per gallon and coal from $4 to $5 per ton.

Lighter Weight Finished Brick—Lower Shipping Costs

The average weight of standard size finished Georgia Kaolin fire-brick is only 6½ lbs. as compared with 7 lbs. average weight of standard size ordinary fire-clay brick. This means a saving of 500 lbs. per thousand brick—an item that reduces freight costs considerably. Freight rates are favorable. Excellent rail and water service exists for shipment of finished brick to all points north and west.

Savannah—the Gateway to a Great Fire-Brick Market

The Georgia refractory clay deposits are only 150 miles by rail from the port of Savannah, through which finished brick can be economically shipped by rail or water to any point on the Atlantic seaboard. It is the water and rail gateway to the great fire-brick markets of this country and the seaport for steamer shipment to the great markets of Cuba, Central and South America. Better fire-brick is needed in all of these countries—think of the possibilities that await the refractory products manufacturers that establish a branch plant in Georgia!

Ask Our Co-operation!

The Central of Georgia Railway, as a result of extensive common sense research, has compiled valuable up-to-date information pertaining to the opportunities that exist in Georgia for refractory products manufacturers. Ask our co-operation—we want to see you succeed in Georgia!

Central of Georgia Railway

J. M. Mallory
Gen'l Industrial Agent

CENTRAL GEORGIA

233 West Broad St.
Savannah, Ga.

BUYERS' GUIDE (continued)

E

Electrical Instruments
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

Electric CO_2 Meters (Recorders)
Brown Instrument Co.
Engelhard, Chas., Inc.

Electrical Porcelain Machinery
Mueller Machine Co., Inc.

Enameling Equipment, Complete
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
The Porcelain Enamel & Mfg. Co.

Enameling Furnaces
Caulkins & Co., H. J.
Chicago Vitreous Enamel Product Co.
Holcroft & Co.
Parker Russell Co.
The Carborundum Co. (*Carboradiant*)
The Massillon Refractories Co. (*"Alumite"*)
The Porcelain Enamel & Mfg. Co.
U. S. Smelting Furnace Co.
Vitro Mfg. Co.

Enameling Muffles
Parker Russell Co.
The Carborundum Co.
(*Carbofrax*)
The Massillon Refractories Co. (*"Alumite"*)

Enameling, Practical Service
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Harrop, C. B.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

Enamels, Porcelain
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

Engineering Service
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Harrop. C. B.
Parker Russell Co.

Equipment (Porcelain Enameling)
Chicago Vitreous Enamel Product Co.
The Porcelain Enamel & Mfg. Co.

Equipment (pressed Steel)
Commercial Shearing and Stamping Co.

Extruding Machines (Lab. Use)
Chambers Brothers Co.

F

Factory Construction
Harrop. C. B.

Feldspar
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co. (*Isco*)
Pennsylvania Pulverizing Co.
Roessler & Hasslacher Chemical Co.

Filtering Machinery
Mueller Machine Co., Inc.

Fire Brick
Parker Russell Co.
The Carborundum Co.
The Massillon Refractories Co. (*"Alumite"*)

Flint
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co. (*Carrara*)
National Silica Co.
Pennsylvania Pulverizing Co.

Flint Pebbles
Alsing, J. R. Eng. Co.

Frit
Ferro Enamel Supply Co.
Porcelain Enamel & Supply Co.
Vitro Mfg. Co.

Fuel
Seaboard Fuel Corp.

Furnaces
Caulkins & Co., H. J.
Chicago Vitrous Enamel Product Co.
Ferro Enamel Supply Co.
Harrop. C. B.
Holcroft & Co.
Parker Russell Co.
The Carborundum Co. (*Carboradiant*)
The Porcelain Enamel & Mfg. Co.
U. S. Smelting Furnace Co.

Furnaces (Electrical)
Engelhard Chas., Inc.
Holcroft & Co.

Furnaces (All Types)
The Massillon Refractories Co. (*"Alumite"*)

G

Glazes and Enamels
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

Granulators
Lancaster Iron Works, Inc.

Going to the CERAMIC CONVENTION?

then don't fail to see
the Wonderful Clay Deposits
at Macon

IN central Georgia, only a short ride from Atlanta, are deposits of kaolin and other clays unequalled in quality, quantity and proximity to markets by anything in America!

At the convention of the American Ceramic Society in Atlanta, February 8-15, you will have an opportunity to inspect Georgia clays which have proven so superior in the manufacture of white ware, sanitary wares, floor and wall tile, electrical porcelain and refractories. You will see great mines in operation, employing the latest methods—yet hardly scratching the surface of the immense deposits. Here is an opportunity for you to get first-hand information as to why clay products can be manufactured in Georgia at lower production cost and transportation cost than in any other section.

The City's Yours

Make This Pleasure Trip!

As a feature of the convention program there will be a trip to Macon and the Georgia clay belt. Macon is one of the older cities in the United States and has many places of historic interest. You will find Southern hospitality and entertainment at its best! We invite you personally to come see us and take advantage of this trip.

Chamber of Commerce
MACON GEORGIA

BUYERS' GUIDE (continued)

Gold
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

H

Hearths
The Carborundum Co.
(*Carbofrax* heat treating)

Hearths (High Aluminous Clay—Electrically Sintered Aluminum Oxide—Silicon Carbide)
The Massillon Refractories Co. (*"Alumite"*)

Hygrometers (Electric)
Engelhard, Chas., Inc.
Harrop. C. B.

I

Impervite (Refractory and Hard Porcelain)
Engelhard, Charles, Inc.

Infusorial Earth
Harrop. C. B.
Innis, Speiden & Co.

Iron (Enameling)
The Mansfield Sheet & Tin Plate Co.
United Alloy Steel Corp.

J

Jiggers
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

K

Kaolin
Edgar Plastic Kaolin Co.
Harshaw, Fuller and Goodwin Co.
Roessler & Hasslacher Chemical Co.
United Clay Mines Corp.

Kilns (Tunnel)
Harrop. C. B.

Kilns (china, decorating)
Caulkins & Co., H. J.
Holcroft & Co.

Kiln Castings
Lancaster Iron Works, Inc.

Kilns (China-Decorating)
The Massillon Refractories Co. (*"Alumite"*)

Kryolith
Harshaw, Fuller & Goodwin Co.
Pennsylvania Salt Mfg. Co.

L

Linings (Furnace-Refractory Block-Refractory Plate, Brick and Tile)
Alsing, J. R. Eng. Co.
Norton Co.
The Carborundum Co.
The Massillon Refractories Co. (*"Alumite"*)

Lehrs (High Aluminous Clay—Electrically Sintered Aluminum Oxide—Silicon Carbide)
The Massillon Refractories Co. (*"Alumite"*)

M

Magnesite
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Manganese
Harshaw, Fuller & Goodwin Co.
Hy-Grade Manganese Co.

Metals (Porcelain Enameling)
The Mansfield Sheet & Tin Plate Co.
United Alloy Steel Corp.

Mills (Pebble-Tube)
Alsing, J. R. Eng. Co.

Minerals
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Roessler and Hasslacher Chemical Co.
Vitro Mfg. Co.

Mixing Machines
Chambers Brothers Co.

Mold Holders
Commercial Shearing and Stamping Co.

Molds (Brick)
Lancaster Iron Works, Inc.

Molding Machines
Freese, E. M. & Co.

Muffles (Furnace)
Norton Co.
The Carborundum Co. (*Carbofrax*)
The Massillon Refractories Co. (*"Alumite"*)

Muriatic Acid
Harshaw Fuller and Goodwin Co.
Pennsylvania Salt Mfg. Co.
Roessler and Hasslacher Chemical Co.

N

Nitrates (Cobalt, Sodium)
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

O

Oil Burners
Best, W. N. Corp.
Harrop. C. B.

Opacifiers
Harshaw, Fuller & Goodwin Co.
Titanium Alloy Mfg. Co.

Operators (Coal)
Seaboard Fuel Corp.

Oxides
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co.
Metal & Thermit Corp.
Paper Makers Importing Co., (Inc.)
Pennsylvania Salt Mfg. Co.
Roessler and Hasslacher Chemical Co.
Titanium Alloy Mfg. Co.
Vitro Mfg. Co.

Written by Users of
TAM
OPAX
"You know, of course, that we are using Opax exclusively now. I am using the same percentage that I did of tin oxide, 6% of the frit added in the mill, and although I cannot say it is any better it certainly is just as good. We would not tolerate the slightest lowering of the quality of our white."
"I felt my way slowly with Opax, starting with 3% Opax and 3% tin oxide. This combination was used for several weeks, and then I started to increase until I eliminated all of the tin. I have used nothing but Opax since the middle of November."
Dec. 23, 1925
BY THE ENAMELING SUPT. OF A 12 FURNACE ENAMELED COOKING WARE PLANT
"In the first place, OPAX has entirely replaced tin oxide in our plant. We use it in both the smelting and the mill, in both Cast Iron and Steel enamels."
Dec. 28th. 1925
BY THE ENAMELER OF A 7 FURNACE PLANT MANUFACTURING ENAMELED STOVE PARTS
"Up to this time, I have only been able to replace 5% of our 8% of tin oxide added at the mill, with OPAX. This mill mix we have used regularly for some time. This gives us a saving of $16.00 per thousand pound mill load, an item certainly worth considering." Dec. 26th. 1925
BY THE ENAMELING SUPT. OF A 6 FURNACE SPECIALTY ENAMELING PLANT
AMERICA
THE WORLD
gram, subject to the terms on back hereof, which are hereby agreed to.
Dec. 31, 1925
Ship immediately four tons Opax through freight from Chicago. Advise.
BY THE PURCHASING AGENT OF A LARGE PLANT MANUFACTURING ENAMELED BATH TUBS
The Titanium Alloy Manufacturing Co.
Works at Niagara Falls, N. Y.
CERAMIC MATERIALS DEPARTMENT
R. D. LANDRUM GENERAL MANAGER
8007 EUCLID AVENUE, CLEVELAND, OHIO

TAM
ZIRCONIUM & TITANIUM
PRODUCTS FOR
THE CERAMIC INDUSTRIES

BUYERS' GUIDE (continued)

P

Pallets (Steel)
Commercial Shearing and Stamping Co.

Pans (Wet and Dry)
Chambers Brothers Co.
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Pebble Mills
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Pins
Potters Supply Co.

Placing Sand
Pennsylvania Pulverizing Co.
National Silica Co.
United Clay Mines Corp.

Plate Feeders
Chambers Brothers Co.
Hadfield-Penfield Steel Co.

Plates (Filter)
Norton Co.

Porcelain Enameling Service, Practical
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Harrop. C. B.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

Porcelain Enamels
Chicago Vitreous Enamel Product Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

Pots (Glass House)
Buckeye Clay Pot Co.

Potash (Carbonate)
Innis, Speiden & Co.

Pottery Machinery
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Pug Mills
Chambers Brothers Co.
Freese, E. M. & Co.
Hadfield-Penfield Steel Co.
Lancaster Iron Works, Inc.
Mueller Machine Co., Inc.

Pulverizing Machinery
Alsing, J. R. Eng. Co.
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Pulverizing Mills
Alsing, J. R. Eng. Co.
Hadfield-Penfield Steel Co.
Mueller Machine Co., Inc.

Pumps
Mueller Machine Co., Inc.

Pyrometers (Indicating)
Brown Instrument Co.
Engelhard, Chas., Inc.
Harrop. C. B.
Leeds & Northrup Co.

Pyrometers (Recording)
Brown Instrument Co.
Englehard Chas., Inc.
Harrop. C. B.
Leeds & Northrup Co.

Pyrometer (Switches)
Brown Instrument Co.
Engelhard, Chas., Inc.
Leeds & Northrup Co.

Pyrometer Tubes (Refractory and Hard Porcelain)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
The Massillon Refractories Co. *("Alumite")*

R

Recording Instruments
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

Recuperators
The Surface Combustion Co.

Refractories
The Massillon Refractories Co. *("Alumite")*
The Carborundum Co.
Norton Co.
Parker Russell Co.
United Clay Mines Corp.

Refractory Materials
Parker Russell Co.
The Massillon Refractories Co. *("Alumite")*
United Clay Mines Corp.

Regulators (Automatic Temperatures)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

S

Saggers
The Carborundum Co.
Norton Company
Potters Supply Co.

(When writing to advertisers, please mention the JOURNAL)

Founded 1869

B. F. DRAKENFELD & CO. INC.

50 Murray St. New York

Manufacturers

OXIDE OF CHROME GREEN

Special for Glassmakers and Potters
Guaranteed over 99% Pure

Contains no Free Sulphur nor Sulphides

Write for samples of Light and Dark Shades and Copies of analyses

(When writing to advertisers, please mention the JOURNAL)

BUYERS' GUIDE (continued)

Sagger Boards (Steel)
Commercial Shearing and Stamping Co.

Sagger Presses
Chambers Brothers Co.
Hadfield-Penfield Co.
Mueller Machine Co., Inc.
Watson-Stillman Co.

Screens
Newark Wire Cloth Co.

Selenite of Sodium
Drakenfeld and Co., B. F.
Harshaw, Fuller & Goodwin Co.
Vitro Mfg. Co.

Shippers (Coal)
Seaboard Fuel Corp.

Silex Blocks
Alsing, J. R. Eng. Co.

Silica Brick
Parker Russell Co.

Sillimanite (Synthetic)
Norton Co.

Slabs (Furnace)
Norton Co.

Smelters
Chicago Vitreous Enamel Product Co.
Ferro Enamel Supply Co.
Parker Russell Co.
The Massillon Refractories Co. *("Alumite")*
U. S. Smelting Furnace Co.

Soda Ash
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Sodium Antimonate
Harshaw, Fuller & Goodwin Co.
Metal & Thermit Corporation
Vitro Mfg. Co.

Sodium Fluoride
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Spar
Eureka Flint and Spar Co.
Harshaw, Fuller & Goodwin Co.
Pennsylvania Pulverizing Co.

Spurs
Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Steel Equipment
Commercial Shearing and Stamping Co.

Stilts
Potters Supply Co.

Sulphuric Acid
Drakenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Pennsylvania Salt Mfg. Co.
Roessler and Hasslacher Chemical Co.

T

Tachometers
Brown Instrument Co.

Talc
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Tanks
Lancaster Iron Works, Inc.

Temperature Instruments (Measuring)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leed & Northrup Co.

Thermocouples
Brown Instrument Co.
Engelhard, Chas., Inc.
Leeds & Northrup Co.

Thermometers (Electric Resistance)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.

Thimbles (Filtering Extraction)
Norton Co.

Tile Machinery (Floor and Wall)
Mueller Machine Co., Inc.

Tin Oxide
Harshaw, Fuller & Goodwin Co.
Metal & Thermit Corp.

Titanium
Titanium Alloy Mfg. Co.

Tubes (Insulating)
Engelhard, Chas., Inc.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.

Tubes (Pyrometer)
Brown Instrument Co.
Engelhard, Charles, Inc.
Leeds & Northrup Co.
McDaniel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
The Massillon Refractories Co. *("Alumite")*

ENGLISH AND DOMESTIC

QUALITY

POTTING

CLAYS

Paper Makers Importing Co., Inc.

EASTON, PENNA.

BUYERS' GUIDE (continued)

V

Vacuum Pumps
Mueller Machine Co., Inc.

W

Wet Enamel
Chicago Vitreous Enamel Product Co.
The Porcelain Enamel & Mfg. Co.
Ferro Enamel Supply Co.
Vitro Mfg. Co.

Whiting
Darkenfeld and Co., B. F.
Harshaw, Fuller and Goodwin Co.
Innis, Speiden & Co.
Roessler and Hasslacher Chemical Co.

Winding Drums
Lancaster Iron Works, Inc.

Witherite
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Z

Zirconia
Titanium Alloy Mfg. Co.
Vitro Mfg. Co.

BALL
SAGGER } CLAY {
WAD

H. C. SPINKS CLAY CO.
NEWPORT, KY.
MINERS and SHIPPERS
Write for samples

ALPHABETICAL LIST OF ADVERTISERS

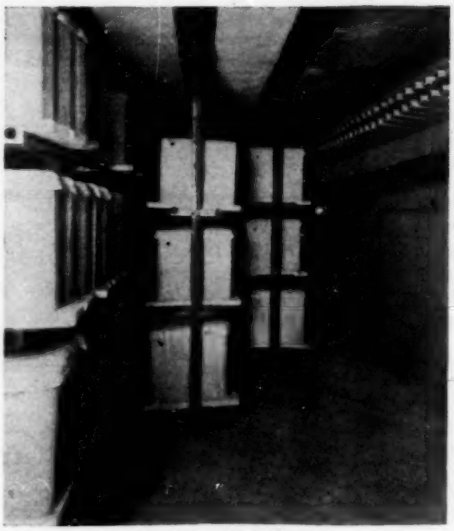
	Page
Alsing Engineering Co.	30
American Trona Corp.	21
Best, W. N. Corp.	31
Brown Instrument Co.	24 and 25
Buckeye Clay Pot Co.	29
Cain Machine Co.	27
Carborundum Co.	36
Carrier Engineering Co.	18
Caulkins & Co., H. J.	19
Central of Georgia Railway	7
Chambers Brothers Co.	28
Chicago Vitreous Enamel Product Co.	21
Commercial Shearing & Stamping Co.	39
Drakenfeld and Co., B. F., Inc.	13
Edgar Plastic Kaolin Co.	Inside Back Cover
Engelhard, Charles, Inc.	32
Freese, E. M. & Co.	21
Hadfield-Penfield Steel Co.	32
Harshaw, Fuller and Goodwin Co.	32
Holcroft & Co.	27
Hy-Grade Manganese Co., Inc.	27
Innis, Speiden & Co., Inc.	31
Journal of the Society of Glass Technology	20
Lancaster Iron Works, Inc.	34
Leeds & Northrup Co.	1
Macon Chamber of Commerce	9
Mansfield Sheet & Tin Plate Co.	34
Massillon Refractories Co.	29
McDanel Refractory Porcelain Co.	27
Montgomery Porcelain Products Co.	28
Mueller Machine Co.	19
National Silica Co.	35
Newark Wire Cloth Co.	5
Norton Co.	38
Paper Makers Importing Co. (Inc.)	15
Parker-Russell Co.	27
Pennsylvania Pulverizing Co.	31
Philadelphia Drying Machinery Co.	40
Porcelain Enamel & Mfg. Co.	Outside Back Cover
Potters Supply Company	35
Proctor and Schwartz, Inc.	23
Professional Directory	26
Roessler and Hasslacher Chemical Co.	Inside Front Cover
Seaboard Fuel Corporation	22
Spinks, H. C. Clay Co.	16
Titanium Alloy Mfg. Co.	11
United Alloy Steel Corp.	33
United Clay Mines Corp.	27
U. S. Smelting Furnace Co.	3
Vitro Manufacturing Co.	30
Watson-Stillman Co.	28

(When writing to advertisers, please mention the JOURNAL)

At Atlanta

you may see exhibited

Shop No. 1.
at the
Atlanta Biltmore



The Ejector Dryer shown here applied to sanitary ware is adaptable to rooms or tunnels for all types of ware.

The Carrier Ejector System Dryer

The Carrier Ejector Dryer provides automatic control of Humidity, Temperature, Air Motion and Schedules. It is designed upon sound engineering principles derived from extensive laboratory study and applied practice in the drying of all forms of ceramic ware.

Bring your Problem with you.

Carrier Engineering Corporation

Offices and Laboratories,

750 Frelinghuysen Ave., Newark, N. J.

The Revelation Kilns

OIL or GAS

Pottery Kilns, China and Glass Decorating Kilns, Enameling Furnaces, Dental and other High Heat Furnaces.

Special No. 6—Pottery

Thousands choose the Revelation Kiln.

Those who have used the Revelation Kiln longest are its most enthusiastic admirers.

H. J. CAULKINS & CO.

AMERICAN STATE BANK BUILDING
State and Griswold Sts., DETROIT, MICH.

CLAY MACHINERY!

SAGGER ROOM	SLIP HOUSE	GRINDING ROOM
Grog Pans	Blungers	Clay Crackers
Pug Mills	Agitators	Pulverizers
Sagger Presses	Lawns	Cage Grinders
Wad Mills	Pumps	Dust Screens
Grog Screens	Filter Presses	Pebble Mills
PRESS ROOM	**GREEN ROOM**	**GLAZE ROOM**
Tile Presses	Jiggers	Glaze Mills
Faience Presses	Pull Downs	Agitators
Porcelain Presses	Cleaning Wheels	Lawns
Dies & Equipment	Batting Machines	Pumps

THE MUELLER MACHINE CO.

TRENTON, N. J.

CLASSIFIED ADVERTISING

New Advertising Rates Effective January 1, 1926

Classified advertising for this page for positions wanted or positions vacant, can now be listed at the new rate of $1.00 for 35 words. Address the

Advertising Manager
American Ceramic Society
Lord Hall, O.S.U. Columbus, Ohio

POSITION WANTED

as plant executive or control engineer by ceramic engineer of broad training and experience whose specialty is porcelain. However, will consider position in any line. Address **Box 72/14 American Ceramic Society, Lord Hall, O. S. U., Columbus Ohio.**

The Journal of the Society of Glass Technology

A quarterly Journal containing original papers and abstracts of papers covering the whole field of Glass Technology.

ANNUAL SUBSCRIPTIONS TO SOCIETY (Including Journal)

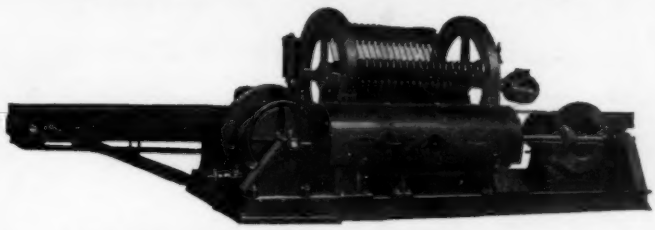
Ordinary Members	$ 7.00
Collective Members	15.00
Price per Number to non-Members	2.50
Price per volume (unbound) to non-Members	9.00

Forms of application for membership may be obtained from the American Treasurer of the Society, Mr. Wm. M. Clark, Ph.B., Nela Park, Cleveland, Ohio.

Address orders and inquiries to: The Secretary, Society of Glass Technology, The University, Sheffield, England.

(When writing to advertisers, please mention the JOURNAL)

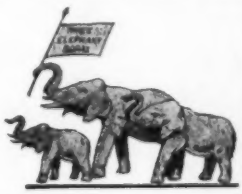
The Georgia Whites Are Cut On The Freese Cutter



And Molded On The Freese Union Machine

E. M. FREESE AND COMPANY, Galion, Ohio
Dependable Machinery of Proven Efficiency

THREE ELEPHANT BORAX
99.5% PURE
Its uniform high quality guarantees the excellence of your product.
We also make Boric Acid Guaranteed 95% pure
Write for our price and samples today.



AMERICAN TRONA CORPORATION
Woolworth Building, New York, N. Y.

Quality ***Uniformity*** ***Service***
LUSTERLITE ENAMELS
MANUFACTURERS
FURNACES - - SPEED FORKS - - ENAMELS
Complete Enamel Shop Supplies and Equipment
STOCK CARRIED
Chicago Vitreous Enamel Product Company
1407-47 S. 55th Court, Cicero, Ill., U. S. A.

(When writing to advertisers, please mention the JOURNAL)

COAL FACTS

Factors to Consider When Buying Ceramics Coals

1) The Reliability of the source of supply.

2) The Adaptability of the Coal for Your Specific Purpose.

3) The Promise of a Definite Delivery Date, and—

4) The Purchase Price.

Controlling, as we do, our own source of supply, we are able to take care of Factor No. 1.

Having Specialized for years in supplying Coal to Ceramic Plants and Potteries—there is no doubt about Factor No. 2.

If we make a promise of Delivery, we keep that promise. This takes care of Factor No. 3.

Fair dealing over a Period of Years, together with the fact that we are continually selling Coals to Ceramic Plants and Potteries at a fair Price—is the answer to Factor No. 4.

260 South Broad St. Philadelphia

SEABOARD FUEL CORPORATION

No. 1 Broadway New York City

(When writing to advertisers, please mention the JOURNAL)

"Proctor"

DRYING MACHINERY

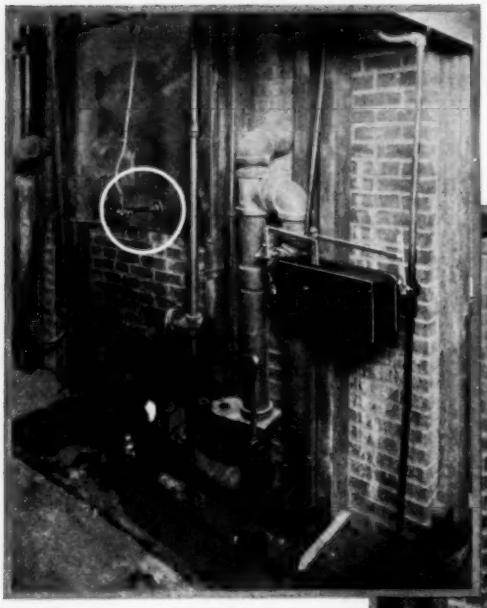
for all Clay Products

Electrical Porcelain
Sanitary Ware
General Ware in Molds
Dipped General Ware
Clay Rolls : Spark Plugs
Saggers : Tile
Refractories : Brick
Chemical Stoneware

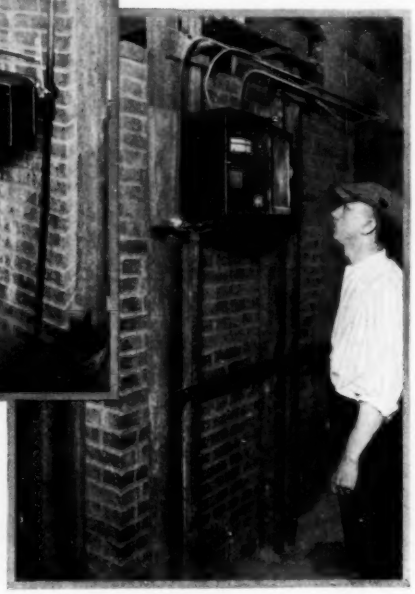
PROCTOR & SCHWARTZ, INC.
PHILADELPHIA, PA.

(When writing to advertisers, please mention the JOURNAL)

"We could not afford doing nothing but watch-



At left: Brown Automatic Fuel-Supply Regulating Valve used with Brown Automatic Temperature Control. The valve-operating mechanism is enclosed in the metal case seen at the right of this view. Can be furnished to open or close the valve in any desired ratio with temperature variation.



At right: Brown Indicating Pyrometer governing the Brown Automatic fuel-supply control valve shown above closing or opening it as temperature rises or falls. Operation is positive, close control assured.

Brown Automatic

(When writing to advertisers, please mention the JOURNAL)

to keep one man ing the fuel control valves"

How many, many plant managers have struggled with this problem!

The Buck Stock & Range Company, St. Louis, Mo., were unable to get satisfactory results from hand regulation of temperature in their cast-iron-enameling furnaces. "We could not afford," says Mr. Anthony Jennings, Jr., Superintendent of their enameling department, "to keep one man doing nothing but watching the fuel control valves. Consequently, temperature was continually getting too high or too low."

Under these circumstances (quite usual on any exacting industrial heating operation under hand control) their steel-enameling furnace—which was equipped with Brown Automatic Temperature Control—far surpassed its iron-enameling fellow in output, quality and operating economy. So of course Brown Automatic Temperature Control was added to the cast-iron-enameling unit.

The results summarized by Mr. Jennings are: "More pieces enameled—better work—25% less fuel—and no hand-control troubles—netting 374% annual return on the installed cost of the Brown equipment."

Address—The Brown Instrument Company, 4587 Wayne Avenue, Philadelphia, Pa., or any of our district offices at New York, Boston, Pittsburgh, Cleveland, Detroit, Chicago, Indianapolis, Birmingham, Tulsa, Houston, El Paso, Denver, Salt Lake City, Los Angeles, San Francisco and Montreal.

Temperature Control

(When writing to advertisers, please mention the JOURNAL)

PROFESSIONAL DIRECTORY

THE SHARP-SCHURTZ CO.
Chemists for the Ceramic Industry
We have fully equipped laboratories at
Lancaster, Ohio, U. S. A.

KARL LANGENBECK
Consulting Ceramic Engineer
1625 Hobart St. N. W., Washington, D. C.
Competent men for responsible
positions in the clay
industries, available.

CERAMIC BREVITIES

Golding-Keene Co. of Keene, N. H., have just completed building a new grinding mill at Trenton, N. J., for the production of both flint and spar.

The new company is incorporated under the name of the Standard Flint & Spar Corp., and is now ready for commercial grinding.

The Co-operative Foundry Company, of Rochester, New York, is planning to double the capacity of their porcelain enameling department.

The Porcelain Enamel & Manufacturing Company, of Baltimore, has been given the contract for this work.

THE PARKER RUSSELL CO.
ST. LOUIS

BUILDERS OF
RO-MACK Enameling Furnaces
HIGH TEMPERATURE FURNACES
For all Purposes

HIGH GRADE REFRACTORIES

TRADE MARK
Pyrometer Tubes—Protection Tubes—Combustion Tubes
McDanel Refractory Porcelain Company
Beaver Falls, Pennsylvania

UNUSUAL · SHAPES · OUR · SPECIALTY

HIGH GRADE
CLAYS
OF EVERY KIND—FOR EVERY PURPOSE
UNITED CLAY MINES CORPORATION TRENTON, N. J.

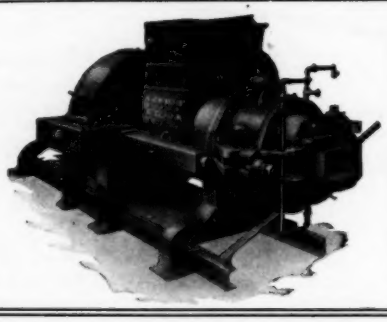
Continuous Tunnel Kilns Vitreous Enameling Furnaces
HOLCROFT & CO.
6545 Epworth Blvd. Detroit, Mich.

We are manufacturers of
POTTERY and CERAMIC
machinery
Please let us know your requirements
The Cain Machine Co. East Liverpool, Ohio

USE "HY-GRADE" MANGANESE
for surface and body coloring. We pay special attention to our 200 mesh powder that will not "Cat Eye" in glazes.
We mine and very carefully prepare every pound of our own product.
HY-GRADE MANGANESE COMPANY, Inc.
WOODSTOCK, VIRGINIA

If you want pyrometer protection tube satisfaction
USE
Montgomery Hard Porcelain Pyrometer Tubes
All Sizes and Lengths for either Platinum or Base Metal Couples
The Best Liked and Most Largely Used
Protection Tubes on the Market today
If the manufacturer of your pyrometer equipment cannot supply you, write us direct.
TRADE MARK
MONTGOMERY PORCELAIN PRODUCTS CO.
FRANKLIN, OHIO, U. S. A. 10-22

Brick Making Machines
Crushers Grinders Mixers
Automatic Cutters
Chambers Bros. Co.
Philadelphia Pennsylvania



WATSON-STILLMAN SAGGER PRESSES
MAKE BETTER SAGGERS
at
LOWER COST

Showing a 50 Ton Sagger Press Outfit Complete equipped with dies for making Elliptical Sagger.

These Machines press saggers from solid wads of clay. Our sagger dies have no joints to work loose or open under pressure; this insures a homogeneous product and reduces to a minimum the losses in firing.

Write for Bulletins and full information

THE WATSON-STILLMAN CO.
28 DEY STREET, NEW YORK
Chicago, McCormick Building
Philadelphia, Widener Bldg.
Cleveland, Auditorium Garage Bldg.

Let "ALUMITE" Refractories

Assist You in Meeting Competitive Prices

With 38 Years Experience behind us in supplying the most exacting needs of the Enamel, Glass, Pottery and other Ceramic Industries, we can undoubtedly assist you by reducing your Furnace Maintenance to the minimum and eliminating costly Production Interruptions. Our Engineering Dept. is at your service. CONSULT US.

Send for Bulletins No. 19 and 20 also samples

THE MASSILLON REFRACTORIES CO.

(*Founded by W. G. Hipp*)
MASSILLON, OHIO
On the Lincoln Highway **Convenient for Truck Delivery**

GLASS MELTING POTS
DOMESTIC CLAY
GERMAN CLAY
RINGS & BOOTS

TANK BLOCKS
BOTTOM GRADE
FLUX GRADE
POT CLAY GRADE

NEXT TIME—
SPECIFY

"BUCKEYE"

On Your Requisition and Be
Convinced of Their
QUALITY AND SERVICE

HIGH GRADE FIRE CLAYS
BENCH CLAY
MORTAR COMPOUND

THE BUCKEYE CLAY POT CO.
TOLEDO, OHIO

HIGH GRADE STANDARD AND SPECIAL REFACTORIES

COMPLETE STOCKS OF
VITREOUS PORCELAIN BRICK
For Pebble Mill Linings
VITREOUS PORCELAIN BALLS
Used as a Grinding Medium in Place of Flint Pebbles on White Materials
IMPORTED SILEX LINING BLOCK
FRENCH OR DANISH PEBBLES
PEBBLE, TUBE and BALL MILLS

J. R. ALSING ENG. CO., Inc.
50 CHURCH ST., NEW YORK
Established Since 1869
Pottery: Parkersburgh, W. Va.

Pottery Machinery
Tile Machinery
Brick Machinery

can be advertised profitably in the *JOURNAL*. If you are interested in reaching hundreds of users of your product, your announcement should appear in these columns.

—

Complete details upon request

—

American Ceramic Society
(Advertising Department)
Lord Hall, O. S. U. Columbus, O.

CHROME OXIDE **CADMIUM SULPHIDE**

VITROZIRCON

The ideal opacifier

THE VITRO MFG. CO. TRADE MARK PITTSBURG, PA.

COLORING OXIDES

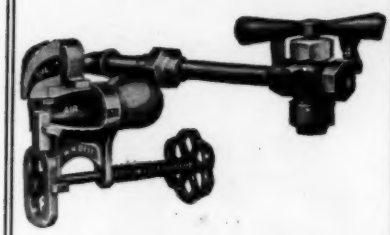
Uniform — Strong

ENAMELS

For Stoves, Signs, Sanitary and Kitchen Ware

ANTIMONY OXIDE **COPPER OXIDES**

W. N. BEST
Oil Burners



The BEST Since 1890

Write for catalogs and list of users in the Ceramic field

W. N. BEST Corporation
11 Broadway New York City

1816 CHEMICALS 1926

"Over a Century of Service and Progress"

South Dakota
FELDSPAR

An extremely high-grade Potash Spar ground in our own mills under constant and thorough chemical control.

Capacity up to 300 Tons Daily

We solicit your inquiries

INNIS, SPEIDEN & CO., Inc.
Importers, Manufacturers, Exporters
46 CLIFF STREET NEW YORK

Branches:
BOSTON PHILADELPHIA
CHICAGO CLEVELAND
GLOVERSVILLE

PENNSYLVANIA PULVERIZING CO.
LEWISTOWN, PA.

Pure Canadian Potash Feldspar
Potters Flint Placing Sand

SALES OFFICE
323 Fourth Avenue
Pittsburgh, Pa.

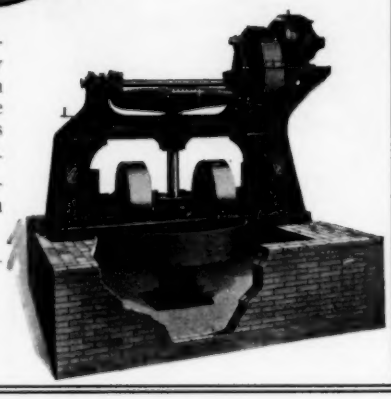
THE CERAMIC INDUSTRY'S BEST ASSET

BUILT RIGHT RUN RIGHT FOR CLAY WORKERS

The best Asset of the Ceramic Industry is quality of product and quality of product is largely dependent on properly prepared Materials. The American Wet Grinding Pan does its work thoroughly, quickly and cheaply.

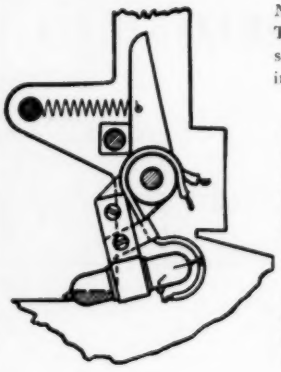
This is an unusually well built, dependable unit. Long on service. Light on power. Ask for Bulletin.

We build a complete line of machinery for Ceramic needs.



The Hadfield-Penfield Steel Co.
BUCYRUS, OHIO

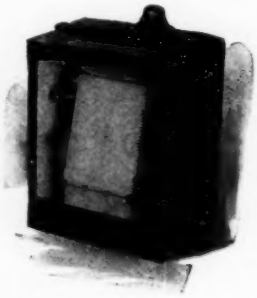
Mercury Switch Solves Problem



No more electrical contact troubles on pyrometer recorders. This sketch shows our new Mercury Contact Switch—the small glass bulb containing mercury. See the contact points inside the bulb at the right? See the mercury at the left?

When the bulb is tilted the other way the mercury envelopes the contact points and you have a flow of current. It is UNFAILING.

Ask for Bulletin No. 28 and learn about the OTHER many advantages of Engelhard Recorders.

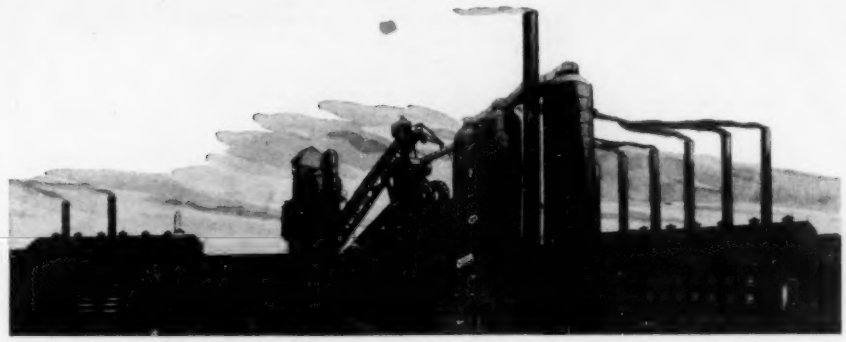


Charles Engelhard, Inc.

30 Church Street **NEW YORK CITY**

Factory: Newark, N. J.

(When writing to advertisers, please mention the JOURNAL)



Cheapness is expensive regardless of price

It is not low price that determines the economy of an enameling base metal, but rather low cost of production in the enameler's plant.

TONCAN METAL

Inferior enameling metal is so much harder to handle in the shop, and results in so many "culls" which must be consigned to the scrap heap, that the total production cost is higher than if Toncan had been used.

Toncan Enameling Sheets are the result of specially selected raw materials, careful attention to every detail in melting and rolling, and most rigid inspection at every step.

Toncan Enameling Sheets are manufactured with one object in view—to produce an enameling base that is as sound and as free from defects as it can be made. Such a base permits you to produce a better finished product at considerably less cost. Write for information.

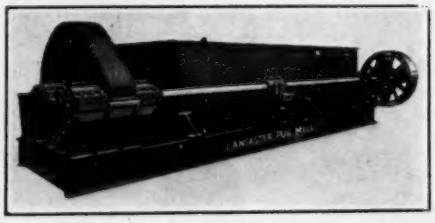
UNITED ALLOY STEEL CORPORATION
CANTON, OHIO

New York	Chicago	San Francisco
Syracuse	Detroit	Indianapolis
Cleveland	Pittsburgh	Portland
	Philadelphia	

TONCAN ENAMELING SHEETS

(When writing to advertisers, please mention the JOURNAL)

New Clay Cleaner
Granulators
Autobrik Machine
Disintegrators
Crushers
Steam Pipe Rack Dryers
Cable Conveyors
Window Drums
Belt Conveyors
Brick Molds
Clay Storage Systems
Clay Cars
Kiln Castings
Tanks and Stacks



Better Clay Tempering with LancasterPug Mills

In preparing clay for the manufacture of soft mud or stiff mud brick or heavy clay products, Lancaster Pug Mills go to the heart of your problem. They are designed to give unusual efficiency in clay tempering—to deliver a thoroughly mixed and perfectly uniform clay, which will result in a strong clay product.

Lancaster Pug Mills accomplish the maximum amount of work with the minimum of power. They are very rugged and will bear the brunt of continuous heavy duty without slow-down for repairs or replacement. They are dependable under the most trying conditions.

LANCASTER IRON WORKS, Inc.
LANCASTER, PENNSYLVANIA
BRICK MACHINERY DEPARTMENT JAMES P. MARTIN, Manager

WABIK METAL
QUALITY M PRODUCTS

After an exhaustive study of the requirements of the Enameling Industry we are producing:

WABIK METAL
SPECIAL VITREOUS ENAMELING SHEETS

Unlike ordinary steel sheets, warping and blistering is reduced to a minimum, thus increasing the Enameler's output and profit.

Many of the leading plants now recognize "WABIK METAL" as the supreme stock for that beautiful permanent lustre which is so essential in Table Tops, Stove Parts, Refrigerator Parts, Signs, etc.

THE MANSFIELD SHEET & TIN PLATE CO.
MANSFIELD, OHIO

(When writing to advertisers, please mention the JOURNAL)

SERVICE TO POTTERS

We Manufacture—
- PINS
- STILTS
- THIMBLES
- SPURS
- SAGGERS
- CRUCIBLES
- TILE for Decorating kilns

We Sell—
- BALL CLAY
- SAGGER CLAY
- WAD CLAY
- GROUND FIRE CLAY
- BITSTONE
- FIRE BRICK
- IMPORTED PARIS WHITE

THE POTTERS SUPPLY COMPANY
EAST LIVERPOOL, OHIO

The National Silica Co.
OREGON, ILL.

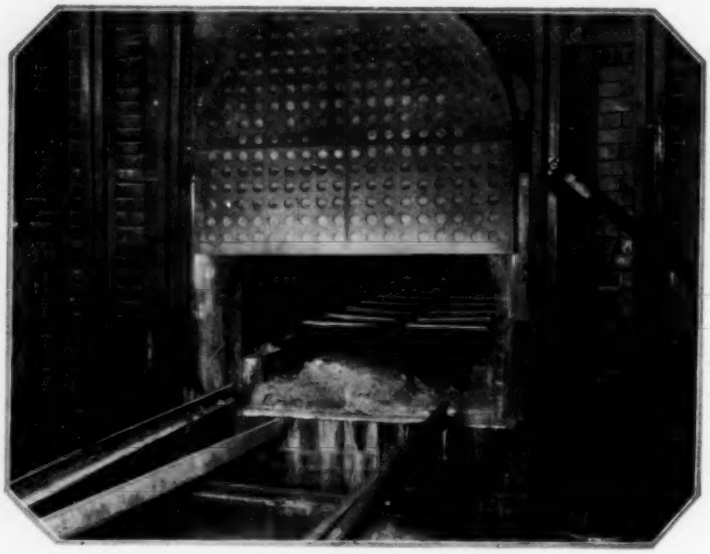
Producers and Pulverizers of

FLINT

exclusively for

Pottery Purposes

99.97% Pure Silica 140 Silk Lawn Test



A Carbofrax Muffle that Served Fifteen Thousand Hours

NOT counting time out for noon hours or for bringing the furnace up to heat, a Carbofrax Muffle gave 15,164 hours of actual productive service at the plant of the Erie Enameling Co.

Even then it was good for longer life. The only reason they took the muffle out was to dismantle the furnace because of moving into their new plant.

They found that the muffle was still in good condition—tight joints—no cracking or spalling and no evidence of disintegration.

With this muffle the yearly average on oil consumption was seven gallons per hour.

The furnace was used to burn cast iron parts at night but ran on sheet steel during the day. The temperature was raised from 1200° to 1600° F. in less than one hour every morning.

Increased production at lower burning costs, better burned ware, a quicker, more uniform distribution of heat—these were the results they got and the results that you will get from

CARBOFRAX, THE CARBORUNDUM REFRACTORY

THE CARBORUNDUM COMPANY, PERTH AMBOY, N. J.

Pacific Abrasive Supply Co., Los Angeles and San Francisco, California
Williams & Wilson, Ltd., Montreal, Canada Christy Firebrick Company, St. Louis
Harrison & Company, Salt Lake City, Utah

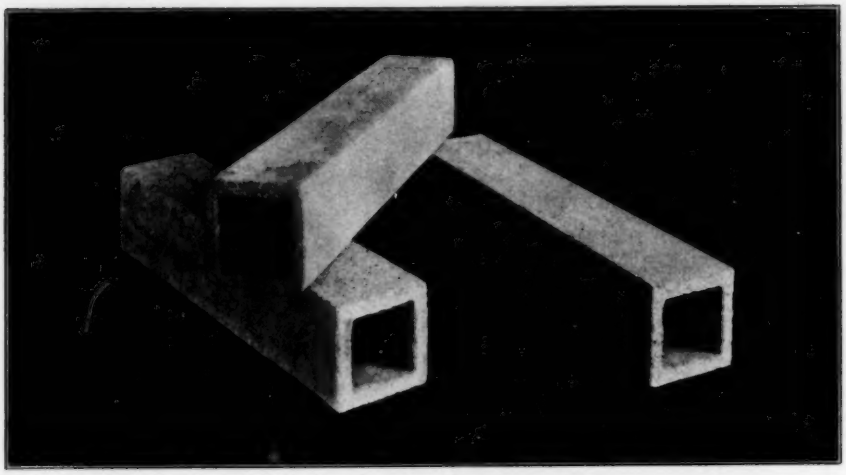
WHO DO YOU TRY TO REACH

with your advertising? The kiln burner or the engineer in charge of the plant? The readers of the Journal make up the greater number of the engineers with whom you want to get in touch. By using Journal advertising space it identifies you and your product as being worthy. The trust placed in you by Journal readers means increased sales.

Advertising Department

American Ceramic Society

Lord Hall, O. S. U. **Columbus, Ohio**



Alundum Recuperator Tubes

Industry and Refractories

The demands are for higher duty products. New processes at more elevated temperatures need full consideration from the

Chemical
Physical and
Thermal Standpoints.

As a Manufacturer of

Refractories for Heavy Duty

we extend our co-operation to the user.

To meet modern conditions the following NORTON Products are offered:

ALUNDUM (bonded fused alumina)
CRYSTOLON (bonded silicon carbide)
FUSED MAGNESIA

Some of the uses of the above are in Refractory Cements, Bricks, Plates, Linings, Muffles, Saggers, Recuperator Tubes, Tunnel Kiln Combustion Chambers and Furnace Parts.

NORTON COMPANY
WORCESTER, MASSACHUSETTS **U. S. A.**

(When writing to advertisers, please mention the JOURNAL)

The Commercial Shearing & Stamping Co.

YOUNGSTOWN, OHIO.

PRESSED STEEL EQUIPMENT FOR THE ENTIRE CERAMIC INDUSTRY

Drying Boards or Shods for Terra Cotta — Sewer Tile Conduit — Sanitary Ware

Brick Pallets for Clay — Silica Magnesite — Concrete

WARE AND PLATFORMS SAGGER BOADS STEEL RACKS GRINDING WHEEL BATS

MOLD HOLDERS FOR CHINA WARE INSULATORS

We hope to see you all at Atlanta. This is one time of the year when we have the opportunity to meet in person and talk over things pertaining to our favored industry—ceramics. If you have a problem let us know about it—we want to help solve it if possible.

ADVERTISING DEPARTMENT

AMERICAN CERAMIC SOCIETY,

Lord Hall, O. S. U. COLUMBUS, OHIO

HURRICANE DRYING
The Ideal Way

The ideal feature of "HURRICANE" drying lies in the fact that quality improvement and reduced cost of operation go hand in hand. Ware is so placed and air circulation so controlled that overdrying in some places in order to dry thoroughly in others has been eliminated. That both improves quality and saves money. We can show you clearly how it is done.

Tunnel Truck, Humidity, Automatic Continuous Dryers

THE PHILADELPHIA DRYING MACHINERY COMPANY

Stokley St. above Westmoreland Philadelphia, Pa.

Canadian Agents:
Whitehead, Emmans, Ltd.
Montreal

HURRICANE
Ideal Drying Every Day

New England Agency:
Hurricane Engineering Company
53 State St., Boston, Mass.

EDGAR CLAYS

Home Office

METUCHEN, N. J.

Mines

Edgar, Fla., Okahumpka, Fla., Mc Intyre, Ga., Milltown, N. J.

"Just Real Good Clays"

Read this testimonial

Jan. 7, 1926.

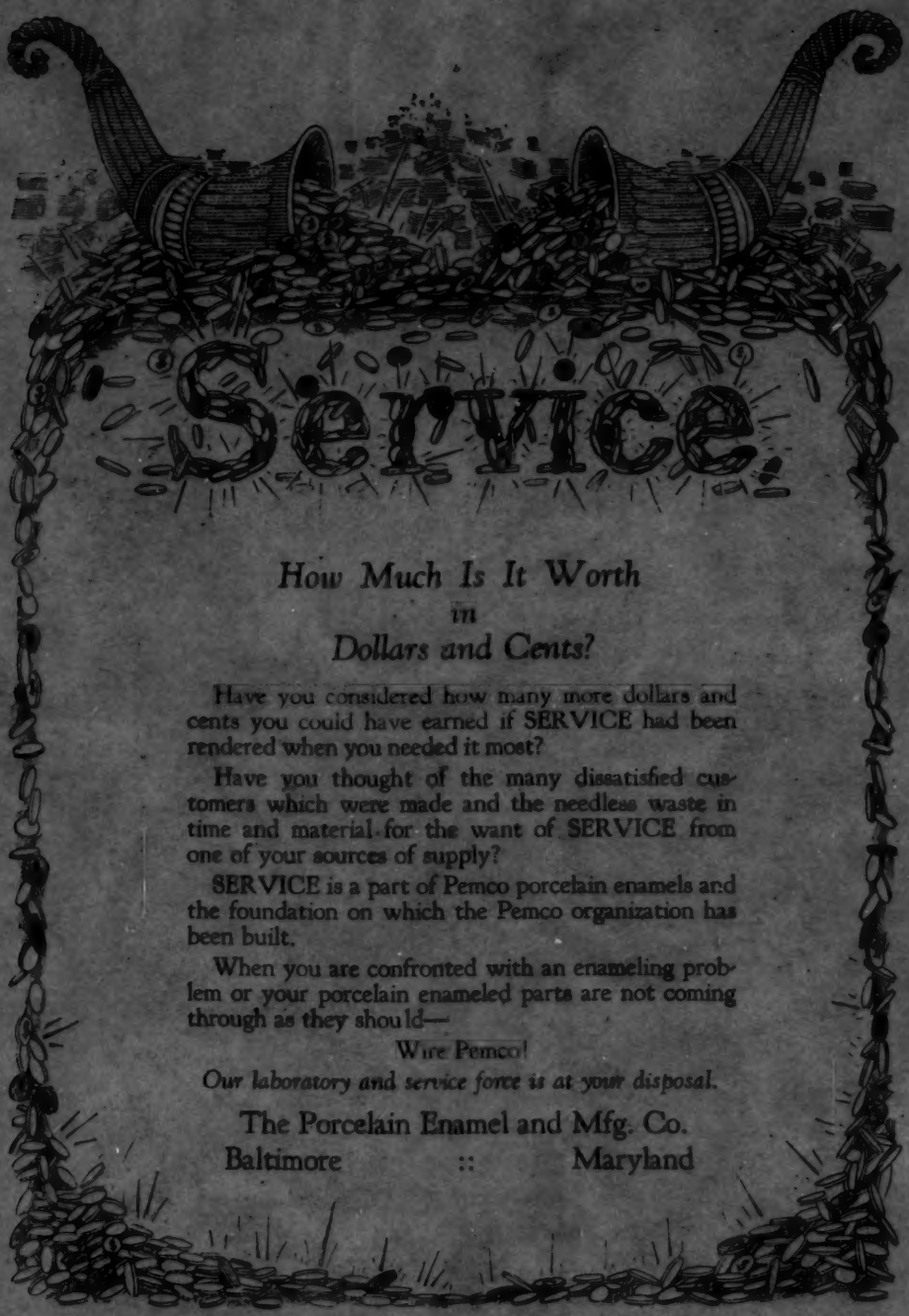
Dear L. E. R., Jr.:

Thank you very much indeed for the calendar. I will order all my clay from the Edgar Company in the future, and should I need a plumber or a chemist, I will send direct to you. I feel that I shall need some "Sagger" very soon, I am beginning to sag at the waist and around the shoulders. I am so glad that Edgar service is free, it's about the only thing these days where you get something for nothing. I shall recommend your "Sant's Colonial" to my wife because she is interested in anything that makes a Wonderful Body. I am surprised that our good Elder allows "Edgar No. 8" to be mixed in Terra Cotta to produce a grog body, haven't we enough illicit stuff on the market without Edgars going in the business? We are sorry to have to complain in this letter, but really we used your No. 8 with 10% Kryolith for a low fire and it put the fire out. We prefer soft coal even though it isn't washed.

In closing, I may say that we are doing our best to develop an "All American Body." It won't be your fault or ours if it eventually does not become 100% American.

Thanking you for washing and uniformity, and deploring the fact that you wash the grit out of Klondyke clays, leaving no chance for us to pan out the gold for ourselves,

I am Sir,
Yours in Saggers,
F. Z.



How Much Is It Worth in Dollars and Cents?

Have you considered how many more dollars and cents you could have earned if SERVICE had been rendered when you needed it most?

Have you thought of the many dissatisfied customers which were made and the needless waste in time and material for the want of SERVICE from one of your sources of supply?

SERVICE is a part of Pemco porcelain enamels and the foundation on which the Pemco organization has been built.

When you are confronted with an enameling problem or your porcelain enameled parts are not coming through as they should—

Wire Pemco!

Our laboratory and service force is at your disposal.

The Porcelain Enamel and Mfg. Co.

Baltimore :: Maryland